Draft

WORK PLAN

ENGINEERING EVALUATION/COST ANALYSIS
ARKEMA IN-WATER REMOVAL ACTION

PORTLAND, OREGON

Prepared for

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ACRONYMS AND ABBREVIATIONS

AINW	Archaeological Investigations Northwest Inc.
AOC	administrative order on consent
ARAR	applicable or relevant and appropriate requirements
ATT	aquatic toxicity test
BEDS	biological effects database for sediments
bgs	below ground surface
BNAs	base-neutral acid extractables
CAD	confined aquatic disposal
CAS	Columbia Analytical Services, Inc.
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	chemicals of concern
COI	constituents of interest
CPD	City of Portland Datum
CPT	one penetrometer test
CRD	Columbia River Datum
CSF	cancer slope factor
C/S-F	concentration/screening factor
CSM	conceptual site model
CST	column settling test
CU	consolidated, undrained
DDD	dichloro-diphenyl-dichloroethane
DDE	dichloro-diphenyl-dichloroethene
DDT	dichloro-diphenyl-trichloroethane
DEQ	Oregon Department of Environmental Quality
DNAPL	dense non-aqueous phase liquid
DQO	data quality objectives
DRET	dredging elutriate test
DSL	Division of State Lands
EE/CA	engineering evaluation and cost analysis
EET	effluent elutriate test
EPA	United States Environmental Protection Agency
ER-L	effects range low
ER-M	effects range medium
FCR	field change record
FS	feasibility study
FSP	field sampling plan
GUS	Gregory Undisturbed Sampler

IRM	interim remedial measure
LL	liquid limit
LWG	Lower Willamette Group
LWR	Lower Willamette River
MCB	monochlorobenzene
MPR	manufacturing process residue
NA	natural attenuation
NAPL	non-aqueous phase liquid
NAS	Northwest Aquatic Services, Inc.
NCP	National Contingency Plan
NOAA	National Oceanographic Atmospheric Administration
NTCRA	non-time critical removal action
PAHs	polycyclic aromatic hydrocarbons
PBT	persistent bioaccumlative toxins
PCB-Aroclors	polychlorinated biphenyls-aroclors®
PCB-Congeners	polychlorinated biphenyls-congeners
PCP	pentachlorophenol
PEC	probable effects concentrations
PEL	probable effect level
Pesticides	organochlorine pesticides
PI	plasticity index
PID	photo-ionization detector
PL	plastic limit
PRE	preliminary risk evaluation
PRG	preliminary remediation goals
PTSV	principal threat screening values
QAPP	quality assurance project plan
RA	removal action
RAA	removal action area
RAO	removal action objectives
RFD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
RPD	relative percent difference
SAP	sampling and analysis plan
SBLT	sequential batch leaching test
SOW	statement of work
SPT	standard penetration test
SQV	sediment quality values
STA	sediment trend analysis
SVOCs	semivolatile organic compounds

TAL	target analyte list
TBC	to be considered
TCLP	toxicity characterization leaching procedures
TEC	threshold effects concentrations
TEL	threshold effects levels
TLC	thin layer chromotography
TOC	total organic carbon
TPH-D	total petroleum hydrocarbons-diesel and oil range
TPH-G	total petroleum hydrocarbons-gasoline range
TS	total solids
TSCA	Toxics Substance Control Act
UU	unconsolidated, undrained
USACE	United States Army Corps of Engineers
VOCs	volatile organic compounds

1.0 INTRODUCTION

This document is the work plan for the Engineering Evaluation/Cost Analysis (EE/CA) in support of a non-time critical removal action (NTCRA) for the in-water portion of the Arkema Inc. (Arkema) facility in Portland, Oregon (Figure 1-1). The purpose of this EE/CA Work Plan is to summarize and analyze existing information and data for the Arkema site, develop a conceptual model of the fate and transport of chemicals of interest related to historical site operations, evaluate data gaps where additional data may be needed, and, finally, propose a scope of work and sampling plan to complete the EE/CA at the Arkema site.

Integral Consulting Inc. (Integral) is conducting this work under contract with Arkema. This work plan has been prepared in accordance with an Administrative Order on Consent (AOC) for Removal Action and Statement of Work (SOW) signed by Arkema and EPA with an effective date of June 27, 2005 [Docket No. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 10-2005-0191]. An early and essential step in the NTCRA process is the completion of an EE/CA to address chemicals in sediments that are considered principal threat areas. During the EE/CA, a removal action area (RAA) is defined and a focused list of removal actions for the site is evaluated. At the end of the EE/CA process, a preferred removal action alternative is selected to address the principal threat area.

This work plan incorporates several attachments. Altogether, these documents are referred to as the work plan for the Arkema EE/CA:

- *Field Sampling Plan (FSP), EE/CA In-Water Arkema Removal Action, Portland, Oregon (Attachment 1).* The FSP provides specific guidance for field methodology and quality assurance procedures that will be followed by Integral and its subcontractors.
- *Quality Assurance Project Plan (QAPP), EE/CA In-Water Arkema Removal Action, Portland, Oregon (Attachment 2).* The QAPP describes laboratory methodology and quality assurance/quality control (QA/QC) procedures that will be used to complete the EE/CA for the Arkema site.
- *Project Health and Safety Plan (HASP), EE/CA In-Water Arkema Removal Action, Portland, Oregon (Attachment 3).* The HASP has been prepared in conformance with Integral's Health and Safety Plan guidelines and in accordance with Occupational Safety and Health Administration (OSHA) regulations (29 CFR 1910.120) and project requirements. It addresses those activities associated with work to be performed on the Arkema site.

- *Integral Standard Operating Procedures (SOPs).* The SOPs provide specific, detailed information on conducting routine, repetitive field techniques (e.g., split-spoon sampling from a drill rig). These documents are found in Appendix A of the FSP.

1.1 PROJECT BACKGROUND

The Arkema facility is located along the lower Willamette River in the Portland Harbor, which was designated a federal Superfund site by EPA in 2000. The Initial Study Area (ISA) of the Portland Harbor Superfund site encompasses about 5.7 miles of the Willamette River from approximately the southern tip of Sauvie Island to the southern end of Swan Island [river miles (RM) 3.5 to 9.2]. The ISA does not define the Superfund Site; the boundaries of the Site will be determined upon issuance of a Record of Decision (ROD; Integral et al 2004c). The Lower Willamette Group (LWG) – a consortium of the Port of Portland, the City of Portland, and industry – has been working to complete a remedial investigation (RI) of the lower Willamette River. The Arkema facility is located at approximately RM 7.5 immediately upstream of the Burlington Northern Santa Fe (BNSF) Railroad Bridge (Figure 1-1). Inorganic chemicals were manufactured at the Arkema site from 1941 until 2001, when the facility was closed and chemical manufacturing discontinued. For most of the site history, the chemical activities involved electrolytic decomposition of brine solutions to manufacture inorganic chemicals including sodium chlorate, chlorine, sodium hydroxide, hydrogen, and hydrochloric acid. Other chemical manufacturing processes were limited during the site operational history, but included dichlorodiphenyltrichloroethane (DDT) from 1947 to 1954, and ammonium perchlorate from 1958 to 1962.

Arkema (also formerly known as ATOFINA Chemicals, Inc., Elf Atochem North America, Inc., and Pennwalt) has conducted investigations and several Interim Remedial Measures (IRMs) in the upland portion of the site since 1994. In 1995, Arkema (then known as Elf Atochem) submitted an intent to participate in the DEQ's Voluntary Cleanup Program. In 1996, Arkema entered into a voluntary letter agreement with DEQ which was followed in 1998 by a voluntary agreement with DEQ to complete a remedial investigation and feasibility study (RI/FS) of the former DDT manufacturing area. The RI/FS was later expanded to include other areas and chemicals at the site (e.g., hexavalent chromium and perchlorate). For the RI, Arkema completed two phases of in-river investigation to assess the extent of chemicals from the former DDT manufacturing process in nearshore Willamette River sediments and groundwater. Data collected for the Portland Harbor RI/FS, for the site-wide Arkema RI, and for other relevant investigations will be evaluated and used in the EE/CA.

Arkema has proactively implemented several IRMs at the site to address contaminated soil and groundwater. In 2000 and 2001, Arkema, completed two phases of excavation

and disposal to remove surface and subsurface soil with elevated DDT concentrations from the former manufacturing process residue (MPR) pond and trench. Currently, Arkema is conducting vapor extraction and air sparging activities in the upland portion of the site to address residual chlorobenzene in groundwater. Full-scale implementation of groundwater treatments for hexavalent chromium, chlorobenzene, and DDT are ongoing. Treatability studies of *in situ* treatments for perchlorate in groundwater are also ongoing.

1.2 REGULATORY FRAMEWORK

The NTCRA for the Arkema site will be conducted under CERCLA (as amended), 2 U.S.C. §§ 9601 *et seq*. CERCLA Section 121 (d) requires that a cleanup: 1) be protective and, 2) if any hazardous substance will remain on the site, attain a level of cleanup that complies with any legally applicable or relevant and appropriate requirement (ARAR). The following statutes and regulations may include ARARs for the project:

- Clean Water Act and National Toxics Rule [40 Code of Federal Regulations (CFR) 131], which provide water quality criteria (WQC) for protection of human health and aquatic organisms.
- Clean Water Act Section 404 requirements (40 CFR 230), which provides standards for the management of dredged material in rivers and other water bodies.
- Clean Water Act Section 401, which requires that both dredging and dredged material disposal operations not violate applicable effluent standards or water quality standards. EPA, working with Oregon DEQ, will be responsible for certifying that such operations will comply with this requirement.
- Rivers and Harbors Act (33 CFR 230, 322), which prohibits unauthorized activities that obstruct or alter a navigable waterway.
- Resource Conservation and Recovery Act (RCRA) [40 CFR 260, 261], which provides standards for the identification and management of solid and hazardous waste.
- Endangered Species Act (16 USC Section 6901 *et seq.* 50 CFR Part 402), which requires an evaluation of the action's impacts on listed (or proposed for listing) species of fish, wildlife, or plants.

Several state regulations may also be considered ARARs:

- State Water Quality Criteria (OAR 340-41-0442-0445), which provide water quality standards for the state of Oregon.
- Solid Waste Management Regulations (OAR 340-122-010), which provide standards for the management and handling of solid wastes in Oregon.

- Hazardous Waste Regulations (OAR 340-101-0033), which provide standards for the identification and management of hazardous wastes in Oregon.

These and other potential ARARs can be generally categorized as chemical-specific, action-specific, and location-specific. ARARs for each category will be developed, evaluated, and selected in consultation with EPA during preparation of the EE/CA.

1.3 WORK PLAN ORGANIZATION

This work plan includes the following sections and appendices:

- **Section 2.0, Removal Action Area Characteristics**—describes the physical and ecological setting, site history, facility operations, and cultural resources.
- **Section 3.0, Review of Existing Data**—summarizes and reviews the existing chemical, biological, geologic, hydrologic, engineering, and ecological data collected at the site. This section also summarizes the results of data screening in accordance with the AOC requirements.
- **Section 4.0, Preliminary Conceptual Site Model**—describes and synthesizes available information on sources, transport pathways, potential receptor populations, and potential exposure pathways for chemicals of interest in river sediments and groundwater.
- **Section 5.0, Data Gaps and Data Quality Objectives**—identifies the removal action objectives (RAOs) and removal action alternatives considered for the site. Identifies the data gaps that will need to be filled as part of the EE/CA.
- **Section 6.0, Removal Action Characterization Activities**—describes the scope of work that has been developed to fill the data gaps for sediment quality, water quality, engineering, biological, hydrologic, and recontamination source characterization.
- **Section 7.0, Removal Action Evaluation Approach**—summarizes the process and approach to complete the removal action evaluation for the site.
- **Section 8.0, Project Schedule**—presents the proposed NTCRA project schedule, in accordance with the AOC, and includes assumptions about agency and trustee review of project deliverables.
- **Section 9.0, Project Team and Responsibilities**—summarizes the project team and their roles and responsibilities on the project.
- **Section 10.0, References**—lists documents cited in the work plan.
- **Appendix A** – presents geological cross-sections from the Stage 1 and 2 in-water investigation at the Arkema site.

- **Appendix B** – presents the seepage and groundwater study results from the Portland Harbor Superfund Remedial Investigation.
- **Appendix C** – presents the exposure factors and parameters used to develop sediment screening values for wildlife receptors at the Arkema site.
- **Appendix D** – presents chemicals above screening levels and concentration/screening factors for Willamette River sediments

The statement of work (SOW) to the AOC specifies several required elements for the work plan (Appendix B, Section II.1 of the AOC). Table 1-1 summarizes the specific SOW requirements along with the location in the work plan where each element is addressed.

Table 1-1. Required EE/CA Work Plan Elements and the Work Plan Location.

SOW Requirement	Work Plan Location
Respondent shall submit an EE/CA Work Plan that will include a summary of existing information, a project work plan, a Sampling and Analysis Plan (SAP) and a Health and Safety Plan (HASP).	This document is the EE/CA work plan. The Field Sampling Plan (FSP), Quality Assurance Project Plan (QAPP), and Health and Safety Plan (HASP) are attachments to this document.
Introduction/Purpose	Provided in Section 1.0.
Brief description of Arkema Removal Action Area characteristics, including ecological and physical characteristics;	Provided in Section 2.1.
Identification of historic and ongoing sources of contamination to the Arkema Removal Action Area, including past and present operations, drainage, discharges, groundwater seeps, or other releases;	Historic operations which are potential sources of contamination are identified in Section 2.2.3.
Summary of existing information on upstream and upland contamination sources that have the potential to contaminate the Removal Action Area, including a description of environmental investigations, environmental cleanups and planned upland source control measures that will be conducted under agreements with DEQ as the lead agency. The summary of upland source control measures being conducted must contain a schedule for implementation to be completed prior to the EE/CA;	A summary of previous investigations is provided in Section 3. Upland source control measure summaries are provided in Section 4.1.3. The proposed schedule for upland source control is provided in Section 8.
Arkema historical information including dredging history and identification of past and present property owners, operators, and major tenants as well as owners and operators of all immediately adjacent upland properties;	Dredge and fill history is presented in Section 2.2.4. Past and current property owners/operators are identified in Section 2.2.1. Adjacent Property owners are identified in Section 2.2.2.

Table 1-1. Required EE/CA Work Plan Elements and the Work Plan Location.

SOW Requirement	Work Plan Location
Summary of current facility operations and potential access or operational constraints on Work Plan implementation;	Current facility operations are summarized in Section 2.3.
Description of the nature and extent of contamination in the Arkema Removal Action Area, to the extent known, including a summary of existing sediment quality data with a comparison to: Existing ecological sediment quality guidelines that represent a range of levels including, but not limited to, low or no effects (e.g., Threshold Effects Concentrations [TECs], Threshold Effects Levels [TELs], Effects Range Low [ERLs]), as well as levels at which some effects are expected (e.g., Probable Effects Concentrations [PECs], Effects Range Medium [ERMs]). Existing chemistry data will be reviewed to establish Category 1 and Category 2 data categories in accordance with the Portland Harbor RI/FS protocols; Estimated risk-based sediment cleanup values for persistent bioaccumulative toxins (PBTs) that are protective of humans and wildlife that consume aquatic biota from the Willamette River; and Sediment cleanup values that are protective of humans from direct contact with, and incidental ingestion of, chemicals of concern in sediments, riverbank and water. Existing sediment data should be plotted on site maps. Locations with sediment concentrations above the risk based levels in (1) , (2), and (3) above should be indicated on these maps;	The sediment and water screening values are summarized in Section 3.5. The results of screening, supported by tables and figures, are presented in Section 3.6.
Summary of results from sediment toxicity testing conducted to date;	Summary of the results of sediment toxicity data are presented in Sections 3.1.7 and 3.1.12.

Table 1-1. Required EE/CA Work Plan Elements and the Work Plan Location.

SOW Requirement	Work Plan Location
A process for developing a cultural resources survey, and a process for developing procedures to protect and address such cultural resources;	Cultural resource surveys have been conducted on behalf of the LWG for this reach of the Willamette River. The Survey incorporates information for the Arkema site. A summary of the cultural resources in the area is presented in Section 2.4.
Identification of Removal Action Objectives (RAOs), potential Applicable or Relevant and Appropriate Requirements (ARARs), and To Be Considered (TBCs) for the Arkema Removal Action Area;	RAOs are summarized in Section 5.1.1. A preliminary list of ARARs for the Arkema RAA is presented in Section 1.2. A final list of ARARs will be developed though the EE/CA process and in consultation with EPA.
A description of the analysis to be conducted to determine disposal facility or containment options for contaminated sediment;	Tests that will be conducted to evaluate potential disposal options are summarized in Section 5.5.3. The rational and process for evaluating dredging options is summarized in Section 6.3.
A detailed conceptual site model that shows the relationship of the contaminant plumes including, but not limited to: pH variations, hexavalent chrome, perchlorate, monochlorobenzene, DDT and salinity gradients, starting in the uplands and continuing through the riverbank, and into sediment in the river, to the full extent of the data available at the time of submittal; and	The conceptual site model is presented in Section 4.
Other information (including maps and figures) necessary to gain a general understanding of the Arkema Removal Action Area.	This document contains 21 figures that support the interpretation, planning, and presentation, in the work plan.
Respondent shall also identify data gaps that will be filled by the collection and analysis of field data. Investigation activities will focus on problem definition and will result in data of adequate quality and technical content to evaluate the following:	Section 5 presents a summary of the data gaps and the evaluation process that is addressed by the data collection activities detailed in Section 6.

Table 1-1. Required EE/CA Work Plan Elements and the Work Plan Location.

SOW Requirement	Work Plan Location
Nature, extent, and volume of riverbank and sediment contamination including the degree to which riverbank and sediments will need to be removed that represent the principal threat of contamination, an ongoing source of contaminants to the river, and which may represent a recontamination risk to any cap put in place;	Proposed data collection efforts in support of the analysis of the nature and extent of the principal threat area are summarized in section 6.1.1. Recontamination analysis requirements are presented in Section 6.5.
Potential human health and ecological risks resulting from sediment and surface water contamination;	Proposed data collection efforts in support of the analysis of potential human health and ecological risks are summarized in Section 6.1.2.
Engineering characteristics of the Removal Action Area including sediment consistency, dredgeability, potential slope stability issues related to dredging, and potential sediment consolidation issues associated with capping;	Proposed data collection efforts in support of the analysis of engineering characteristics and requirements are summarized in Section 6.2.
Potential water quality effects associated with dredging, piling removal, sheet pile installation, capping, or disposal technologies;	Proposed data collection efforts in support of dredged material characteristics and potential debris are summarized in Sections 6.3 and 6.4.
Technologies for sediment remediation including capping, dredging, treatment, including any necessary treatability testing, and disposal (on-site and off-site);	Technologies under consideration and the process for the EE/CA evaluation are discussed in Sections 5.1.2 and 7.0, respectively.
Identification of upland sources and remedial technologies for source control that Respondent anticipates implementing including a schedule for implementation to be completed prior to the EE/CA;	Sources are presented Section 4. Source control evaluation documentation and schedules are presented in Section 8.

Table 1-1. Required EE/CA Work Plan Elements and the Work Plan Location.

SOW Requirement	Work Plan Location
Assessment of hydraulic control measures, including a sheet pile wall keyed into bedrock across the site, should these be necessary to ensure recontamination risk to in water work (riverbank and sediment cleanup) is eliminated; and	The evaluation of source control measures is incorporated in the data collection efforts outlined in the physical and engineering characteristics data collection efforts outlined in Section 6.2.
Potential impacts to threatened or endangered species, other biological receptors, and the potential habitat benefits and impacts of the removal action.	The proposed data collection efforts in support of the analysis of ecological receptors are summarized in Section 6.1.2.
The procedures Respondent plans to implement when conducting all field activities will be detailed in the SAP for the specific field activity. The initial SAP will be included in the EE/CA Work Plan. The SAP for any field activity will ensure that sample collection and analytical activities are conducted in accordance with technically acceptable protocols that data meet data quality objectives. A SAP provides a mechanism for planning field activities and consists of a Field Sampling Plan (FSP) and a Quality Assurance Project Plan (QAPP). Details are provided in section II of this SOW.	A FSP and QAPP, which make up the SAP, are attachments 1 and 2 to this work plan.
Respondent shall also prepare HASP that is designed to protect personnel from physical, chemical and other hazards posed by field sampling efforts. Details are set forth in Section III of this SOW.	The HASP is attachment 3 to this Work Plan.
Upon request by EPA, Respondent shall also submit copies of previous studies or sampling efforts conducted independently or under local, state or other federal authorities or agreements that are determined by EPA to relate to remedy selection under this Order.	Copies of selected historical data reports were requested and provided to EPA prior to submittal of this work plan

Table 1-1. Required EE/CA Work Plan Elements and the Work Plan Location.

SOW Requirement	Work Plan Location
Additionally, Respondent shall continue to work under DEQ supervision on upland source control actions related to the Arkema Site and that are threatening to be released to the Willamette River, which may include source identification, source prioritization, documentation and tracking of source control plans and completed source control actions, evaluating and documenting effectiveness of source control measures, and providing input to EPA's and DEQ's decision as to effectiveness of source control in order to implement the Removal Action. The goal is for significant upland sources to be controlled to the greatest extent practicable before or during Removal Action implementation such that significant post Removal Action recontamination is not predicted. The EE/CA work plan shall contain a process and schedule for evaluation of the upland source control program. As a result of the evaluation, should it be determined that sources are not being controlled sufficiently to achieve the RAOs, this SOW requires, upon notice by EPA, Arkema to conduct evaluation of hydraulic control measures in the EE/CA, including, but not limited to, installation of a sheet pile wall, such that this Removal Action may occur without the expectation of recontamination. A schedule for such evaluation will be included in the EE/CA work plan.	Arkema is actively working with Oregon DEQ on source control measures. The schedule for source control measure evaluation is provided in Section 8.

2.0 REMOVAL ACTION AREA CHARACTERISTICS

2.1 PHYSICAL AND ECOLOGICAL SETTING

The Arkema facility is located in Portland, Oregon on the northwest bank of the lower Willamette River between approximately RM 6.9 and 7.6. The upland portion of the Arkema site encompasses approximately 54 acres of land. The in-water portion of the site is defined as the land below mean high water (18.1 ft COP)[1]. In-water access to the Arkema facility was historically provided from three docks—from upstream to downstream—the Salt Dock, Dock 1, and Dock 2. The site is bounded to the south (upstream) by the CertainTeed roofing products facility and the Willbridge petroleum storage terminal (comprised of Kinder Morgan, Chevron, and Conoco Phillips). To the north (downstream), the site is bounded by a City of Portland sewer right-of-way that includes a discharge pipe from the groundwater remediation system located on the former Rhone Poulenc site. The City of Portland right-of-way is located immediately south of the BNSF Railroad Bridge (Figure 1-1).

The Arkema facility is located within the heavy industrial sanctuary of northwest Portland. The industrial sanctuary is bounded by US Highway 30 and the Portland Hills west of the site. On the east, the Willamette River has been historically a commercial, industrial, and recreational waterway. The initial removal action area has been approximately defined as the nearshore in-water area extending from the Salt Dock to downstream of Dock 2. The initial RAA includes the nearshore beaches and shallow river-bottom bench, and the western river-bottom slope that defines the edge of the river channel near the docks.

2.2 SITE HISTORY

A summary of the histories of site ownership, adjacent ownership, manufacturing, and dredge and fill operations are presented below. Unless otherwise noted, the information presented below was reported in the Draft RI report (ERM 2004).

2.2.1 Arkema Site Ownership History

The facility manufactured inorganic chemicals from 1941 to 2001. It was constructed and operated by Pennsylvania Salt Manufacturing, which later became known as Pennwalt

[1] The in-water portion of the site below mean low water is leased from the Oregon Division of State Lands (DSL)

Corporation (Pennwalt). Purchased by Societe Nationale Elf Aquitaine (ELF) in 1989, Pennwalt was combined with two other companies in 1990 to form Elf Atochem North America, Inc. In 2000, ELF merged with TOTALFINA to form TOTALFINA ELF and Elf Atochem became ATOFINA Chemicals, Inc. (ATOFINA). In 2004, ATOFINA changed its name to Arkema Inc.

2.2.2 Current Adjacent Site Ownership

The site is bordered on the east by the Willamette River and to the south by CertainTeed [GS Roofing Products; DEQ's Environmental Cleanup Site Information (ECSI) database site 117]. The Willbridge Bulk Fuel Area (ECSI 1549) and Kinder Morgan (ECSI 2104) sites are located immediately south of CertainTeed. Front Avenue borders the site to the north and west. Four sites are located to the west of Front Avenue, upgradient of the site. The sites include Starlink (Rhone-Poulenc; ECSI 155), Gould Industries, Doane Lake (ECSI 36), and Kinder Morgan (ECSI 2104). The Siltronics Inc. site (ECSI 183) is located immediately north of Front Avenue. Additional details on the adjacent properties can be found in DEQ's ECSI database (also refer to Figure 2-1).

2.2.3 Arkema Site Operational History

The Arkema site operated as a chloro-alkali plant throughout most of its history from 1941 until 2001, when the entire facility was shut down due to escalating electricity costs. The facility used electrolytic cells to reduce concentrated sodium chloride brine to produce chlorine, caustic soda, hydrogen, hydrochloric acid, and sodium chlorate (CH2M Hill 1997).

Other key manufacturing processes that have occurred at the facility are summarized below.

2.2.3.1 Acid Plant Area

A detailed summary of the processes used to manufacture DDT, ammonium perchlorate, and hydrochloric acid in the Acid Plant Area is presented in the following sections.

DDT Manufacturing 1947-1954

The pesticide DDT was manufactured in the Acid Plant Area between 1947 and 1954. The raw materials used to manufacture DDT included chloral (trichloroacetaldehyde), chlorobenzene (also known as monochlorobenzene [MCB]), and oleum-104 percent (fuming sulfuric acid).

DDT was manufactured inside the former DDT process building (Figure 2-1). During initial startup, residues of the manufacturing process were reportedly discharged to a floor drain apparently connected to a pipe terminating in the river. The manufacturing process residue (MPR) discharge pipe was located in the vicinity of borehole WB-9 on the northern side of Dock 1 (Integral 2003). From 1948 to 1950, process residues were discharged directly to a MPR pond located northeast of the process building (Figure 2-1). From 1950 until DDT manufacturing ceased completely in 1954, the residue was piped to an MCB recovery system and then east into the shallow MPR pond. The MCB recovery system consisted of a steam stripper in which chlorobenzene was removed from the MPR and returned to the DDT manufacturing process. The entire system was located on a curbed concrete slab. In approximately 1951 or 1952, a trench was reportedly constructed, extending north about 285 ft from the northeastern corner of the former MPR pond (Figure 2-1).

Chemical reactions to form DDT occurred inside the process building, where portable metal pans several feet square were filled with hot DDT. When cooled, the material in the pans was broken with a jackhammer to form large fragments of crystalline material. The crystalline DDT was temporarily stored on an asphalt slab located in the Acid Plant Area.

The DDT at the storage slab was transferred to the southwest corner of Warehouse 2 for milling and grinding inside the warehouse. Dry-processed DDT was loaded into bags and transported from the plant by railcar. The railcar loading area was located on the northern side of Warehouse 2. A small amount of material was dissolved in diesel fuel and loaded into trucks, and possibly railcars, as a liquid for DDT application. The aboveground dissolving tanks were located immediately adjacent to the western side of the DDT process building. This building was extended westward after DDT operations ceased.

Magnesium Chloride Hexahydrate Manufacturing 1952-1962

From approximately 1952 to 1962, a sodium chlorate-based cotton defoliant material was manufactured. Magnesium chloride was delivered to the plant and hydrated to form magnesium chloride hexahydrate. This activity was conducted in the former Warehouse 1. The magnesium chloride hexahydrate was taken to the northern end of the sodium chlorate process area, where it was ground and mixed with sodium chlorate. The blended material was bagged and sold.

Ammonium Perchlorate Manufacturing 1958-1962

From approximately 1958 to 1962, ammonium perchlorate was manufactured in the former DDT process building. During this period, sodium perchlorate was produced inside the chlorate cell room near the south end of the property, and then converted to ammonium perchlorate by using ammonium chloride. This material was sold as a solid

rocket propellant. Some ammonium perchlorate handling took place in Warehouse 3, adjacent to the Acid Plant Area to the southeast.

Hydrochloric Acid Manufacturing 1966-2001

From 1966 to 2001, hydrochloric acid was produced in the general area where DDT had been manufactured (Integral 2004a). This area became known as the Acid Plant. Chlorine and hydrogen were burned together in aboveground towers to form hydrogen chloride vapor. The vapor was absorbed in water to form hydrochloric acid.

2.2.3.2 Chlorate Plant Area

A summary of the processes used to manufacture sodium chlorate and potassium chlorate in the Chlorate Plant Area is presented in the following sections.

Sodium Chlorate Manufacturing 1941-2001

Sodium chlorate manufacturing started in 1941 in the Chlorate Plant Area (Figure 2-1). Chlorate was produced by electrolysis of a sodium chloride solution. Sodium bichromate was added to inhibit corrosion and to improve the electrical efficiency of the process. Historically, the bichromate arrived at the plant in dry form in sealed bags and was stored inside the chlorate department. The bags were opened inside the chlorate cell room and the contents were dissolved in tanks with water. The solution was fed into the circulating liquor in the chlorate cell room.

Beginning in the early 1990s, sodium bichromate was received in 30-gallon metal drums. The drums were also stored inside the chlorate department. The bichromate was dissolved in the 30-gallon drums and then siphoned into tanks for incorporation into the circulating liquor.

Historically, the liquid sodium chlorate product contained sodium bichromate. After completion of a chlorate plant modernization project in 1990, the sodium bichromate was separated from the chlorate solution and returned to the circulating liquor, with very little sodium bichromate remaining in the final chlorate product.

Chlorate solutions were shipped by either truck or barge. Trucks were loaded on the southern side of the Chlorate Plant Area. Barges were loaded at Dock 2.

Potassium Chlorate Manufacturing 1941-1978

Potassium chlorate manufacturing also started in the Sodium Chlorate Area in 1941. Operations were similar to those of sodium chlorate, except that the salt source was potassium chloride rather than sodium chloride. This manufacturing operation terminated in approximately 1978.

2.2.3.3 *Salt Pads*

Salt was the primary raw material used at the site throughout its operational history (1941-2001). The Arkema plant historically received salt (sodium chloride) by ship. The salt was transferred onto asphalt-lined Salt Pads in the southeastern corner of the site (Figure 2-1). The salt was dissolved in water while on the Salt Pads to produce brine for plant manufacturing operations.

2.2.4 Dredge and Fill History

Known dredge and fill activities at Arkema are summarized in Table 2-1. Dredge activity for 1956, 1977, and 1984 was provided by Arkema.

Table 2-1. Chronology of Fill and Dredge Events at Arkema.

Year	Location	Description
After 1953	Along riverbank	Fill placement in the Acid Plant Area bordering the Willamette River after DDT manufacturing ceased. It appears that the bank adjacent to the Acid Plant Area has been filled out toward the Willamette River approximately 200 ft since the 1950s (CH2M Hill 1997). Fill thickness ranges from a few feet in the former DDT manufacturing area to approximately 25 ft along the riverbank (Integral 2004a).
1956	Salt Dock	Two areas dredged to accommodate dock construction. The dredged material was placed behind an earthen berm to form the base of the eastern half of the current salt pads.[a]
1977	Dock 1 and Salt Dock	Three areas dredged. A letter from the plant to USACE requested permission to complete the dredging with a clamshell to an elevation of -30 ft (datum unknown). There is no documentation or confirmation that dredging took place[b]
1984	Dock 1 and Salt Dock	Joint application to USACE and Oregon Division of State Lands to repeat dredging apparently conducted in 1977. Dredging was to be completed to elevation -30 ft (datum unknown) and application was for 500 cubic yards (cy). There is no confirmation that dredging was initiated and completed, but application states dredging to be conducted from 9/17/84 to 9/20/84.

Notes:

[a] 1956: Approximate dredge areas were as follows: an area 175 ft x 1200 ft was dredged to -35 ft extending from Dock 1 to the south end of the current No. 3 Salt Pad (the southernmost pad). A second area within the channel 575 ft x 1225 ft was dredged to -50 ft (datum unknown).

[b] 1977: Dredge Areas: (1) area 200 ft long at northern end of Dock 1; (2) area 150 ft long towards the middle of Dock 1; (3) area 100 ft long along Salt Dock.

2.3 CURRENT AND FUTURE FACILITY OPERATIONS

Chemical manufacturing operations at the facility ceased in 2001. Decommissioning and removal of the manufacturing infrastructure were completed in early 2005. The only structure remaining is the office building at the site entrance on Front Street and certain concrete floor slabs left in place as environmental soil caps. Arkema maintains leases from the Oregon DSL for the docks in the Willamette River, but the docks are not currently in use. Upland remedial activities to address environmental impacts are ongoing. There is no known access or operational constraints on EE/CA Work Plan implementation, although the timing of in-water work must be coordinated with the Oregon Department of Fish and Wildlife (ODFW) fish window.

The facility is located within the Guild's Lake Industrial Sanctuary (formerly the Northwest Portland Industrial Sanctuary), zoned and designated "IH" for heavy industrial use (ERM 2004). Future use of the facility is unknown but will likely be heavy industrial.

2.4 CULTURAL RESOURCES

A comprehensive cultural resource analysis is being conducted for the Lower Willamette Group as part of the RI/FS for the Portland Harbor site and should be completed in 2005. The cultural resources for the Arkema site will be summarized based on the findings of the Portland Harbor study and reported in the Removal Action Characterization Report.

3.0 REVIEW OF EXISTING DATA

3.1 SUMMARY OF PREVIOUS INVESTIGATIONS

A number of sampling efforts have been conducted in the Willamette River and river banks adjacent to the Arkema site since 1996, as listed in Table 3-1. A summary of each investigation that focuses on the principal constituents of interest (COIs) at the site (4,4'-DDT and its metabolites, chlorobenzene, perchlorate, chromium, pH[2], and chloride) is presented in the following sections.

Table 3-1. Summary of Previous Investigations[a].

Investigation (report reference)	Year[b]	No. of Stations	Media Sampled, Measured, or Tested
Studies Completed for the Arkema RI/FS			
Monitoring Well Installation Adjacent to River (ERM 2004, 2005a)	1996-2005	35[c]	Soil and Upland Groundwater
Riverbank Sediment Sampling (Exponent 1999)	1998	6	Sediment
Offshore Sediment Sampling (Exponent 1999)	1999	6	Sediment
Riverbank Soil Sampling (ERM 2004)	2000	6	Sediment
Stage 1 & 2 Groundwater and Sediment Investigation (Integral 2003)	2002-2003	25	Sediment, Sediment Groundwater
Studies Completed for the Portland Harbor RI/FS			
Portland Harbor Sediment Investigation (Weston 1998)	1997	13	Sediment
Seep Reconnaissance Survey (GSI 2003)	2002	17 miles of riverbank	Groundwater Seeps
Round 1 Sediment Investigation (Striplin et al. 2003; Integral 2004)	2002	5	Sediment

[2] All of the pH levels in transition zone water samples collected from the site were within the 6.0 to 8.5 range that is typical for fresh groundwater (Stumm and Morgan 1981, Hem 1992). Seven of 29 transition zone water samples had pH values from 6.1 to 6.4, which is slightly below the 6.5 to 8.5 Oregon standard for fresh surface water bodies (OAR 340-041-0021(1b). Based on these data, pH is not considered a COI for the Arkema in-water RA.

Table 3-1. Summary of Previous Investigations[a].

Investigation (report reference)	Year[b]	No. of Stations	Media Sampled, Measured, or Tested
Sediment Stake Erosion/Accretion Monitoring Study (Anchor 2003, 2004)	2002-2004	1 Transect	Mudline Elevations
Round 2 Beach and Surface Sediment Investigation (Integral 2005a, 2005b)	2004	21	Sediment
Round 2 Subsurface Sediment Investigation (Integral and Anchor 2005; Integral 2005a)	2004	11	Sediment
Round 2A Sediment Toxicity Testing Investigation (Windward 2005)	2004	14	Sediment Toxicity Tests
Monitored Natural Recovery report (Anchor 2005)	2004	1	Sediment
Round 2 Groundwater Pathway Pilot Study (Integral 2005c)	2004-2005	11 Transects	Sediment, Sediment Groundwater, Porewater, Vapor Diffusion Gas

Notes:
[a] Arkema and Portland Harbor Superfund studies met Category 1 data requirements.
[b] Years the field work was conducted.
[c] Includes monitoring wells adjacent to the river installed through July 2005.

3.1.1 Monitoring Well Installation Adjacent to the River (ERM 2004)

From 1996 to 2005, 70 borings were completed for the installation of monitoring wells (including replacement wells MWA-6r and MWA-15r), which included 40 shallow-zone, 25 intermediate-zone, 4 deep-zone, and 1 basalt-zone monitoring well borings. Thirty-five of these wells (–MWA series) were installed along the Willamette River near the top of the river bank (Figures 3-1 through 3-3). Monitoring well borings were advanced using hollow-stem auger, sonic, or cable tool drilling methods to depths ranging from 26 to 70 ft below ground surface (bgs). Where monitoring well borings were advanced through low-permeability silt zones, the borings were cased off to prevent direct vertical hydraulic connection between water-bearing zones.

Soil samples from monitoring well borings were visually inspected and logged for lithology using the Unified Soil Classification System (USCS). In addition, soil samples were collected from discrete depth intervals and many were field-screened after collection. Screening methods applied included thin-layer chromatography (TLC), Sudan IV® hydrophobic dye, photoionization detector (PID), or visual inspection. Selected soil samples were collected for analysis of volatile organic compounds (VOCs),

organochlorine pesticides, total petroleum hydrocarbons-diesel range (TPH-D), total petroleum hydrocarbons-gasoline range (TPH-G), and selected soil physical properties.

Groundwater samples collected from the monitoring wells were analyzed for one or more of the following constituents: VOCs, semivolatile organic compounds (SVOCs), polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides, TPH-D, metals, perchlorate, carbonate/bicarbonate, alkalinity, ammonia-nitrogen, nitrate, nitrite, sulfate, chloride, total organic carbon (TOC), chloral hydrate, *p*-chlorobenzene sulfonic acid, and dissolved methane.[3]

An overview of the geology and hydrogeology of the upland portion of the site through the transition zone is presented in Section 3.2.

3.1.2 Portland Harbor Sediment Investigation (Weston 1998)

In September and October 1997, sediment samples[4] were collected from 13 stations (i.e., SD series) in the vicinity of the Arkema site (Figures 3-1 through 3-3). Sediment samples were collected from either 0 to 0.32 ft or 0 to 2.95 ft below mudline (except for one sample collected from 2.95 to 4.95 ft) with a modified 0.1-m^2 van Veen grab sampler (surface sediment samples) or a 3-in diameter gravity corer configured with a 5-ft core barrel and a 700-lb weight stand. Each sediment sample was analyzed for organochlorine pesticides, base-neutral-acid (BNAs) SVOCs, TOC, EPA Target Analyte List (TAL) metals, and grain size. Selected samples were also analyzed for polychlorinated biphenyls (PCBs), herbicides, and one sample was analyzed for titanium.

The pesticide 4,4'-DDT was detected in 17 of the 19 surface sediment samples analyzed, at concentrations ranging from 0.048 mg/kg (station SD081C, near the northern portion of the site) to 22 mg/kg (station SD092, adjacent to Dock 2). Its metabolite 4,4'-DDD was detected in all 19 surface sediment samples analyzed, at concentrations ranging from 0.002 mg/kg (station SD100) to 29 mg/kg (station SD092). The 4,4'-DDE metabolite was detected in 6 of 19 surface sediment samples analyzed, at concentrations ranging from 0.002 mg/kg (station SD100) to 0.22 mg/kg (station SD097). The highest 4,4'-DDT and 4,4'-DDD concentrations were located in the vicinity of Docks 1 and 2. The highest 4,4'-DDE concentration was detected just upstream of Dock 1.

[3] Groundwater sample results are not presented in this report but details are provided in the draft RI (ERM 2004).

[4] Sediment samples described in this section and throughout the document are bulk samples that include porewater.

Total chromium was detected in all sediment samples analyzed, at concentrations ranging from 27.6 mg/kg (station SD100) to 50.6 mg/kg (station SD097). The highest total chromium concentration was detected between Dock 1 and the Salt Dock.

3.1.3 Beach Sediment Sampling (Exponent 1999)

In November 1998, beach sediment samples were collected from exposed river sediments at six stations (RB-1 through RB-6) during a relatively low river stage (Figures 3-1 through 3-3). Surface samples were collected using a stainless steel spoon from the depth interval of 0-10 cm (0-0.4 ft) at each sample station. Sediment coring at depths greater than 10 cm was achieved using a titanium drive corer. The maximum penetration depth was less than 35 cm (1.1 ft), except at station RB-6, where penetration reached 90 cm (3 ft).

Surface sediments and sediment core samples were submitted for the analysis of SVOCs, VOCs, pesticides, TOC, and grain size. Each sediment increment was also field-screened using a PID for the presence of VOCs, DDT using TLC, and non-aqueous phase liquid (NAPL) using Sudan IV® hydrophobic dye.

The pesticide 4,4'-DDT was detected at all of the beach sediment sample locations. In surface (0-10 cm) beach sediments, its concentration ranged from 0.034 mg/kg (station RB-5) to 2.4 J mg/kg (station RB-3). The highest subsurface concentration detected was 2.6 mg/kg at station RB-4, located adjacent to Dock 2. The 4,4'-DDD metabolite was detected at all beach sediment stations except RB-5, with concentrations ranging from 0.018 mg/kg (station RB-6) to 0.100 mg/kg (station RB-2) in surface sediments and from 0.018 mg/kg (station RB-4) to 0.360 mg/kg (station RB-2) in subsurface sediments. The highest 4,4'-DDD concentrations in surface and subsurface sediments were detected at station RB-2, located immediately downstream of Dock 1. The 4,4'-DDE metabolite was also detected in all beach sediment samples analyzed, with concentrations ranging from 0.023 mg/kg (station RB-5) to 0.150 J mg/kg (station RB-3) in surface sediments and from 0.028 mg/kg (station RB-4) to 0.310 mg/kg (station RB-2) in subsurface sediments. The highest concentrations in both surface and subsurface sediments were measured at stations RB-2 and RB-3, located between Docks 1 and 2.

Chlorobenzene was not detected in any of the beach samples.

3.1.4 Offshore Sediment Sampling (Exponent 1999)

In January 1999, sediment samples were collected from six offshore stations (OSS series; Figures 3-1 through 3-3). Samples were collected from the surface (0-10 cm) and at subsequent 20-cm increments to a total depth of 90 cm (3 ft). The surface sediment and one or more deeper intervals from each core were submitted for analysis of SVOCs,

VOCs, pesticides, TOC, and grain size. Each subsurface sediment increment was also field-screened using a PID, TLC, and Sudan IV® hydrophobic dye.

In all five surface and all six subsurface sediment samples 4,4'-DDT was detected, at concentrations ranging from 0.017 mg/kg (station OSS003) to 81 mg/kg (station OSS002) in surface samples and from 0.216 mg/kg (station OSS005) to 17 mg/kg (station OSS002) in subsurface samples. The metabolite 4,4'-DDD was detected in all samples, at concentrations ranging from 0.049 J mg/kg (station OSS003) to 11 mg/kg (station OSS004) in surface samples and from 0.147 mg/kg (station OSS005) to 16 mg/kg (station OSS004) in subsurface samples. The metabolite 4,4'-DDE was detected in five surface and four subsurface sediment samples, at concentrations ranging from 0.032 mg/kg (station OSS005) to 1.48 mg/kg (station OSS004) in surface samples and from 0.226 mg/kg (station OSS001) to 1.84 mg/kg (station OSS004) in subsurface samples. The highest concentrations for all three metabolites in both the surface and subsurface were found inshore of and between Docks 1 and 2.

Chlorobenzene was detected in four surface and four subsurface sediment samples, at concentrations ranging from 0.011 mg/kg (station OSS006) to 34 mg/kg (station OSS003) in surface samples and from 0.009 mg/kg (station OSS001) to 18 mg/kg (station OSS003) in subsurface samples. The highest chlorobenzene concentrations were detected at station OSS003, located riverward of Dock 2.

3.1.5 Riverbank Soil Sampling (ERM 2004)

In August 2000, surface (0 to 0.5 ft) soil samples were collected from six riverbank sampling locations (RB-7 through RB-12) and analyzed for organochlorine pesticides, SVOCs, and four metals (cadmium, total chromium, lead, and zinc). One duplicate sample was collected and analyzed for the same suite of analytes. Samples were collected from three paired locations with one sample location near the top of the slope and the second downslope from the first sample location (Figures 3-1 through 3-3). The sample stations were located between Docks 1 and 2.

The pesticide 4,4'-DDT was detected in all seven riverbank soil samples, at concentrations ranging from 2.3 mg/kg (RB-7) to 120 mg/kg (RB-10). Metabolites 4,4'-DDD and 4,4'-DDE were also detected in all seven riverbank soil samples at concentrations ranging from 0.094 mg/kg (RB-7) to 1.7 mg/kg (RB-8) and 0.81 mg/kg (RB-7) and 3.5 mg/kg (RB-10), respectively. The highest 4,4'-DDT concentrations were detected in the northernmost pair of sample locations (RB-9 and RB-10), with concentrations decreasing to the south. Additionally, for all paired sample locations, the concentration of 4,4'-DDT in the sample collected near the top of the slope was higher than that in the down-slope sample.

Chromium was detected in all seven riverbank soil samples, at concentrations ranging from 17 mg/kg (RB-10) to 40.7 mg/kg (RB-8).

3.1.6 Seep Reconnaissance Survey (GSI 2003)

In October 2002, a reconnaissance groundwater seep survey was conducted for the Portland Harbor RI/FS. Its objective was to inventory readily identifiable groundwater seeps present between RM 2 and RM 10.5 for the human health risk assessment and groundwater conceptual model (GSI 2003). The survey was conducted in an outboard motor-powered launch by cruising close to the shoreline at low speed while observing the banks for signs of groundwater seepage. The reconnaissance survey was conducted during a low stage period on the Willamette River after a drier than normal summer and fall. More bank and beach areas were exposed during this low stage, which increased the likelihood of observing seeps.

No seeps were observed at the Arkema site during the reconnaissance survey.

3.1.7 Round 1 Sediment Investigation (Striplin et al 2003, Integral 2004b)

In 2002, samples of sediment, tissue, or both were collected from five stations (07 series) in the river adjacent to the Arkema site (Figures 3-1 through 3-3). Surface sediments were collected from 0 to 15 cm (0.5 ft) using either a 0.1-m^2 van Veen grab sampler or a 0.3-m^2 hydraulic power grab sampler. Biological sampling methods are described in the Round 1 Field Sampling Report (Striplin et al. 2003).

Beach sediments were collected from one station and analyzed for conventionals (e.g., TOC), metals, PCB-Aroclors, pesticides, SVOCs, and herbicides. Co-located sediment and biological samples were collected from three stations. Sediments were analyzed for conventionals, metals, PCB-Aroclors, PCB-congeners, pesticides, SVOCs, and poly chlorinated dibenzo dioxins/furans (PCDDs/Fs). Biological sampling included the collection of one or more of the following: multi-plate benthic community, clam tissue, crayfish, sculpin, and benthic taxonomy. Tissue sample analyte lists are presented in the Round 1 site characterization summary report (Integral 2004).

Total 4,4'-DDT (i.e., sum of 4,4-DDT, -DDD, -DDE) was detected in all three co-located surface sediment samples, at concentrations ranging from 0.0184 T mg/kg (station 07R030) to 10.6 T mg/kg (station 07R006). The highest total 4,4'-DDT concentration was detected between Docks 1 and 2. Total 4,4'-DDT was detected in the beach sediment sample at a concentration of 0.212 T mg/kg (station 07B024). Biological sampling results are presented in the Round 1 Site Characterization Summary Report (Integral 2004b).

3.1.8 Sediment Stake Erosion/Accretion Monitoring Study (Anchor 2003, 2004)

A transect of stakes was deployed at the Arkema site in July 2002 and monitored periodically until January 2004 to assess sediment deposition or erosion rates (Figures 3-1 through 3-3). The sediment stake report indicated that the stakes were "missing" or "disappeared" toward the end of the monitoring sequence. Three stakes were placed along a transect perpendicular to the shoreline near the downstream portion of Dock 2. The stakes were placed at the 10th percentile (low stakes), 50th percentile (median stakes) and 90th percentile (high stakes) of the river stage. Changes in bathymetry between September 2002 and May 2003 were also examined to assess the changes in sediment depth.

The mudline elevation at the low stake at the Arkema site fluctuated between ±2 cm of the initial elevation through July 2003. The final measurement, collected in November 2003, recorded 7 cm of sediment accretion. The mudline elevation at the median stake showed approximately 10 cm of sediment accretion in October 2002, but only 2 cm during the final measurement in March 2003. The mudline elevation at the high stake showed a small (up to 3 cm) sediment accretion over time (the final measurement was collected in December 2002). The high stakes were probably not inundated by the river during most of the study period because the investigation included the seasonal period when river stage is typically at its minimum and least likely to reach the 90th percentile elevation.

Bathymetry changes between September 2002 and May 2003 adjacent to the Arkema site indicate accretion of 7.5 to 15 cm.

3.1.9 Stage 1 & 2 Groundwater and Sediment Investigation (Integral 2003)

The Phase II Stage 1 and Stage 2 investigations were conducted in June 2002 and February through March 2003, respectively. For Stage 1, seven borehole pairs (WB-1 through WB-7) were advanced using direct-push techniques (standard Geoprobe® push-probe rig, a smaller Geoprobe® push-probe unit attached to the bed of a standard pickup truck or a portable tripod Geoprobe® unit) from Docks 1 and 2. For Stage 2, 18 borehole pairs (WB-8 through WB-25) were advanced using a Geoprobe® push-probe rig mounted on a barge. Figures 3-1 through 3-3 show the station locations.

Borehole pairs were advanced through conductor casing using direct-push techniques to refusal (generally basalt). Sediment samples were continuously collected for logging, field screening, and potential analysis through the first conductor casing. Where possible, sediments were composited over approximate 2-ft intervals and screened in the field for VOCs, NAPL, and DDT. Selected Stage 2 sediment samples were analyzed for pesticides.

Groundwater samples were collected from the second conductor casing through a 4-ft stainless steel screen at one or more discrete intervals from each borehole (with the exception of boreholes WB-6 and WB-17) and were analyzed for VOCs and organochlorine pesticides. Selected groundwater samples were analyzed for cations (calcium, magnesium, potassium, sodium) and anions (bicarbonate, sulfate, alkalinity, and chloride). Stage 2 groundwater samples were also analyzed for perchlorate.

Concentrations of 4,4'-DDT greater than 1 mg/kg in surface sediments were generally confined to the landward side of the docks. The highest 4,4'-DDT concentrations (i.e., greater than 100 mg/kg) were found in deeper sediments from 7 to 14.5 feet below mudline on the landward side of Dock 1 (boreholes WB-8, WB-9, WB-11, and WB-24) and inshore of the south end of Dock 2 (near borehole WB-13). Concentrations decreased substantially in surface sediments to the east beyond the docks. The highest 4,4'-DDT concentrations (i.e., greater than 100 mg/kg) were found in deeper sediments from 7 to 14.5 feet below mudline on the landward side of Dock 1.

Concentrations of MCB greater than 1 mg/L and of 4,4'-DDT greater than 0.01 mg/L in sediment groundwater were confined to the landward side of Docks 1 and 2. The MCB and 4,4'-DDT concentrations outside of the docks were substantially lower than those on the landward side of the docks. In groundwater samples collected outside Docks 1 and 2, MCB and 4,4'-DDT concentrations were all less than 0.25 mg/L and 0.0025 mg/L, respectively. Perchlorate concentrations greater than 1 mg/L were found in sediment groundwater in the vicinity of the southern portion of Dock 1. Where analyzed, the highest chloride concentrations were detected on the landward side of Dock 1.

3.1.10 Round 2 Beach and Surface Sediment Investigation (Integral 2005a, b)

In August and September 2004, grab surface sediment samples were collected from 30 stations (i.e., G300 series) in the river adjacent to the Arkema site Figures 3-1 through 3-3). Six of these stations (i.e., G328, G337, G349, G357, G361, and G365) are located in the Willamette River channel adjacent to the Arkema site, but are beyond the area covered by the figures. The samples were collected using a 0.3-m^2 hydraulic power grab sampler. The target sampling interval was 0-30 cm below the sediment-water interface, with a minimum acceptable penetration depth of 20 cm. All samples were analyzed for grain size, SVOCs, pesticides, metals, and TOC. Selected samples were analyzed for ammonia, hexavalent chromium, TPH-D, TPH-G, dioxins/furans, herbicides, PCB-Aroclors, VOCs, pentachlorophenol, total sulfides, Atterberg Limits, specific gravity (10 percent of samples based on grain size analysis), and bioassays.

Total 4,4'-DDT was detected in all 33 surface sediment samples (including field replicates), at concentrations ranging from 0.00079 JT mg/kg (Station G328) to 15.3 JT mg/kg (station G360). The highest total 4,4'-DDT concentrations were detected in nearshore surface sediments between Dock 2 and the Salt Dock.

Total chromium was detected in all surface sediment samples collected in the vicinity of the site, at concentrations ranging from 15.3 mg/kg (station G328, northern portion of site) to 58.4 J mg/kg (station G360, between Dock 1 and the Salt Dock). Hexavalent chromium was detected in 5 of 16 samples analyzed (including field replicates), at concentrations ranging from 0.2 J mg/kg (station G366, slightly downstream of the Salt Dock) to 0.7 J mg/kg (station G344, downstream of Dock 2).

Chlorobenzene was detected in seven of eleven samples analyzed (including field replicates), at concentrations ranging from 0.00019 J mg/kg (station G350, located on the downstream landward side of Dock 2) to 0.00099 mg/kg (station G353-2, located on the upstream landward side of Dock 2).

3.1.11 Round 2 Subsurface Sediment Investigation (Integral 2005b; Integral and Anchor 2005)

In October and November 2004, sediment cores were collected from 16 stations (i.e., C300 series) in the river adjacent to the Arkema site (Figures 3-1 through 3-3). Three of these stations (i.e., C349, C357, and C361) are located in the Willamette River channel adjacent to the Arkema site, but are beyond the area covered by the figures. Subsurface cores were collected over-water using a vessel-deployed vibracore equipped with either a 14-ft or 20-ft aluminum core tube (4-inch diameter). At each core station, a single core was driven to the maximum core tube length (13 ft for the 14-ft core tubes and 19 ft for the 20-ft core tubes) or refusal depth.

At the onshore core processing lab, the majority of the cores were opened using a table saw. After the sediment in each core segment was exposed, the subsurface sample intervals were determined, based primarily on lithology (USCS visual classification) and the minimum (1 ft) and maximum (approximately 4 ft) thickness criteria as stated in the Round 2 FSP (Integral et al. 2004).

A total of 75 sediment samples (including field replicates) were collected from the 16 stations adjacent to the Arkema site. A total of 47 of these samples were analyzed for selected analytes including grain size, Atterberg Limits, specific gravity, SVOCs, pesticides, PCBs, metals, total solids, TOC, hexavalent chromium, TPH-D, TPH-G, VOCs, PCDDs/Fs, herbicides, and pentachlorophenol. Of the sediment samples collected, 28 were archived at the laboratory and not analyzed.

Total 4,4'-DDT was detected in all 34 subsurface sediment samples, at concentrations ranging from 0.0000498 JT mg/kg (station C335, 2.3 ft to 4.2 ft below mudline) to 72.7 JT mg/kg (station C348, 5.0 ft to 7.9 ft below mudline). The highest total 4,4'-DDT concentrations were detected in buried sediments between Docks 1 and 2.

Total chromium was detected in all subsurface sediment samples in the vicinity of the site, at concentrations ranging from 11.5 mg/kg (station C351, 7.0 ft to 11.0 ft below mudline) to 95.8 mg/kg (station C366-1, 3.6 ft to 7.1 ft below mudline). Hexavalent chromium was detected in 6 of 38 samples analyzed (including field replicates), at concentrations ranging from 0.2 J mg/kg and 0.2 JT mg/kg (stations C357, 1.0 to 4.7 ft below mudline; C368, 1.0 to 4.5 ft below mudline; and C366-1, 8.4 ft to 10.4 ft below mudline) to 0.3 J mg/kg (stations C349, 1.0 to 2.0 ft below mudline, and C362, 1.0 to 5.0 ft below mudline).

Chlorobenzene was detected in 9 of 18 samples analyzed (including field replicates), at concentrations ranging from 0.00019 J mg/kg (station C356, 4.5 to 8.4 ft below mudline) to 6.6 mg/kg (station C356, 4.5 ft to 8.4 ft below mudline).

3.1.12 Round 2A Sediment Toxicity Testing (Windward 2005)

From July through October 2004, 14 grab surface (0-30 cm) sediment samples (i.e., G300 series) were collected in the river adjacent to the Arkema site (Figure 3-4). The samples were co-located with surface chemistry samples (Integral 2005a,b) and collected using a power grab sampler deployed from a sampling vessel. Each sample underwent a 10-day *Chironomus tentans* sediment toxicity test and a 28-day *Hyalella azteca* sediment toxicity test. The toxicity tests were also conducted on negative control sediments, collected from a well-established area free of contaminants. The toxicity test results for each test sediment sample were compared against the negative control samples for each batch.

Mortality rates in the toxicity test were more than 25 percent higher than those in the negative control samples for both *Chironomid* and *Hyalella* at four stations near the Salt Dock and between Dock 1 and the Salt Dock. At two stations between Docks 1 and 2 and four of the stations downstream of Dock 2, mortality for both organisms was within 10 percent of the negative control samples. For two of the six stations downstream of Dock 2, *Chironomid* test mortality rates were 10 to 25 percent higher than the negative control at one station and more than 25 percent higher at the other.

The ratio of the mean weight of the organisms in the test sediments to the mean weight of the organisms in the negative control sediments were generally greater than or equal to 80% of the control sample (0.8), with four exceptions. The four test stations whose mean

weight ratios were less than 0.8 included both *Hyalella* and *Chironomid* and appeared randomly distributed across the site.

3.1.13 Monitored Natural Recovery Report (Anchor 2005)

In October 2004, subsurface cores were collected from four stations within the Portland Harbor Superfund study area. Dredging records, bathymetry, site use, and hydrodynamic conditions within the study area were reviewed to identify sediment core locations that showed the potential for net sedimentation and various degrees of natural attenuation processes. A single core (NA-3) was collected at Willbridge Terminal, immediately upstream of the Arkema site (Figure 3-1). Samples were collected from the mudline elevation to a depth of 94 cm (3.1 ft) below the mudline elevation. Radioisotopes beryllium-7, cesium-137, and lead-210 were analyzed from selected depth intervals for sediment dating purposes. Berillium-7 has a relatively short half-life of 53 days and is useful in measuring the biological mixing zone in sediments. Lead-210 and cesium-137 have longer half-lives (22 years and 30 years, respectively) and can provide information on net deposition rates for a location.

Bulk metals, PCBs, PAHs, and DDT were also analyzed in selected samples.

Based on results of the radioisotope dating, the sediments at this station appear to be well-mixed over the entire core depth. Calculation of a net sedimentation rate was not possible. The sediment mixing could be due to active ship movements and propeller wash in the area.

The bulk chemistry results for station NA-3 show a decrease and then an increase in concentration with depth for most organic chemicals.

3.1.14 Round 2 Groundwater Pathway Pilot Study (Integral 2005b)

The groundwater pilot study was conducted at the Arkema site between November 2004 and February 2005. The objective of the pilot study was to evaluate groundwater discharge mapping tools and transition-zone water sampling methods under realistic field conditions for the Willamette River (Integral 2005b). Three groundwater discharge mapping tools were evaluated during the pilot study: thermal infrared imaging, the Trident Probe, and the UltraSeep® system. Five transition-zone water sampling tools were evaluated during the pilot study: the Trident Probe, the UltraSeep® system, large- and small-volume peepers, (vapor diffusion samplers, and power grab sampling, followed by centrifugation.

The groundwater discharge mapping tools and transition-zone water sampling tools were utilized in five transects in the Acid Plant Area and six transects in the Chlorate Plant Area. Pilot study results at the Arkema site are summarized in Section 3.2.

3.2 GEOLOGIC AND HYDROGEOLOGIC DATA

This section summarizes the physical characteristics of the in-water and upland geology and hydrogeology at the site. Specific physical parameters and engineering characteristics are presented in Section 3.3.

3.2.1 Geologic Data

The following sections summarize the in-water and upland geology of the site.

3.2.1.1 In-water Geology

Cross-sections in the vicinity of Docks 1 and 2 are provided in Appendix A (Figures 4a, 5a, 6a, and 7a [Integral 2003]). A cross-section location map is also provided in Appendix A (Figure 1 [Integral 2003]). With increasing distance from the shoreline (eastward), sediments overlying the basalt become finer-grained, thickness of the sediment layer diminishes, and sand horizons become more limited in vertical extent. The increased thickness of sediments on the landward side of the docks is likely due to several factors including increased deposition because of the sheltering effect of the docks, natural sedimentation, dredging, and filling activities in the vicinity of the docks. In general, the sediments represent a fining upward sequence (i.e., coarser sediments at the bottom and finer sediments at the top of the sequence) and become thinner toward the east.

Thin layers (i.e., less than 1 ft thick) of sand and silt were observed in a number of the boreholes and are shown on the cross-sections. Although available data suggest that many of these layers are discontinuous, some of these horizons may nonetheless serve as important controls on the migration of COIs (Integral 2003). Some of these layers appear to dip to the east, consistent with the slope of the basalt surface.

During the Stage 1 and 2 in-water investigation (Integral 2003), the top of the underlying basalt surface was encountered in 20 of 25 boreholes at elevations ranging from -14.3 ft (WB-2) to -43.1 ft (WB-21) City of Portland Datum (CPD) (Integral 2003). The basalt surface generally slopes to the east. There is an apparent high spot (i.e., mound) on the basalt surface around borehole WB-2. There are also two apparent troughs in the basalt surface, one trough centered on Dock 1 and the other just south of Dock 2, near borehole WB-14. The troughs may be erosional features produced by streams that previously flowed into the ancestral Willamette River at these locations.

3.2.1.2 Sedimentation Rates

Sediment accretion and erosion rates based on various studies at the Arkema site are described in the following sections.

Bathymetric Surveys

Five bathymetric surveys were conducted in the Willamette River adjacent to the Arkema site between 1999 and 2004 (Exponent 1999, SEA and David Evans 2003, Anchor 2003, LWG 2004). The surveys were conducted in February 1999, January 2002, September 2002, May 2003, and February – March 2004. Three bathymetric survey difference maps have been generated for the data, the one covering the longest time interval between surveys covers 25 months (January 2002 to February – March 2004; LWG 2004).

This map indicates sediment erosion between Docks 1 and 2 of 0.25 to 2 ft between January 2002 and February 2004. Downstream of Dock 2, there was also generally 0.25 to 2 ft of erosion. Between Dock 1 and the Salt Dock, there was both sediment erosion and accretion. Immediately downstream of the Salt Dock there was 0.25 to 1 ft of erosion; upstream of Dock 1 there was 0.25 to 2 ft of accretion. The winter 2004 bathymetric survey was conducted immediately following a relatively high flow event on the Lower Willamette River (LWG 2004).

Sediment Stake Survey

The sediment stake study on the downstream side of Dock 2 referenced in Section 3.1.8 (Anchor 2003, 2004) indicated 7 cm of accretion between July 2002 and November 2003 at the low stake, an accretion rate of 5.3 cm per year. Less accretion (2 cm) was measured at the median stake between July 2002 and March 2003 which represents approximately 3 cm per year. Sedimentation rates were not estimated for the high stake because the survey occurred when the river stage was least likely to reach the high stake.

Radioisotope Study

As discussed in Section 3.1.13, a single core (NA-3) was collected at Willbridge Terminal, immediately upstream of the Arkema site (Anchor 2005). Sediment accumulation rates could not be determined from the analytical data.

Dredging History

As described in Section 2.2.4, permission was requested from the USACE to dredge the areas around Dock 1 and the Salt Dock in 1977. In addition, a joint application to the USACE and the Oregon DSL was submitted in 1984 to repeat the dredging that was completed in 1977.

Discussion

Bathymetric surveys (LWG 2004) indicated sediment erosion downstream of and between Docks 1 and 2 over the 2 years of study. Both deposition and erosion occurred between Dock 1 and the Salt Dock over the same period. The sediment stake survey indicated a small amount of sediment accretion at both the low and median stakes after 8 to 16 months of monitoring. The radioisotope study results were generally inconclusive for the core collected at the Willbridge Terminal.

The above-referenced studies examined sedimentation rates over relatively short periods of time. Accretion and erosion rates tend to fluctuate with the river stage and velocity, but over time, reveal either net accretion or erosion. The only long-term (e.g., 20 years) data available are qualitative. This information, in the form of dredging history, indicates sufficient accretion adjacent to Dock 1 and the Salt Dock to have required dredging at least twice between 1956 (when the Salt Dock was built) and 1984. Although the sedimentation rate cannot be quantified, the preponderance of data indicates there is a net long-term sediment accretion in these areas.

3.2.1.3 Upland Geology

Results of the remedial investigation indicated the following regarding upland site geology (ERM 2004; Integral 2004a):

- The surficial geology at the site is characterized by fill and alluvial deposits of the Willamette River.
- The eastern portion of the upland site, generally between Docks 1 and 2, has been filled with debris consisting of asphalt, concrete, pipe, soil, and fill from other sources (e.g., City of Portland). These materials occur from the surface to depths of approximately 25 ft bgs.
- The native soil profile is generally characterized by laterally discontinuous, alternating layers of dark gray-brown sand with various amounts of silt and thinner silt layers with various amounts of fine sand. The layers vary from massive to finely laminated.
- Underlying the deepest silt layer, at a depth of approximately 35 ft bgs[5], is a sand layer with black sands adjacent to the river in the Acid Plant area and dark gray-brown sands toward the southern end of the plant.

[5] The deepest silt layer is continuous throughout the Acid Plant area and somewhat discontinuous in the Chlorate Plant area as you approach the river.

- Columbia River Basalt is present below the fill and alluvium at the upland portion of the site at depths of 49 to 55 ft bgs.

Cross-sections that include the eastern upland portion of the site and extend into the Willamette River are provided in Appendix A (Figures 2a, 2b, and 2c [Integral 2005c] and 7a [Integral 2003]).

Fill materials occur from the surface to depths of approximately 25 ft bgs and consist of brown clayey silt to silty sand with occasional wood, brick, concrete, metal piping, and asphalt. Historically, fill materials were used to extend the ground surface out into the Willamette River. Fill thickness ranges from a few feet in the former DDT manufacturing area to approximately 25 ft along the riverbank. In some areas of the site, the ground surface has thus been extended into the river by as much as 200 ft. The majority of the filling activities were conducted after DDT operations ceased in the Acid Plant Area in 1954.

3.2.2 Hydrogeologic Data

Sediment groundwater was studied at the Arkema site during two investigations, the Phase II Stage 1 & 2 in-water sediment and groundwater investigation (Integral 2003) and the Groundwater Pathway Assessment Pilot Study (Integral 2005a). The pilot study focused on shallow sediment groundwater in the transition zone and the Stage 1 and 2 investigation focused on deeper sediment groundwater.

3.2.2.1 Transition-Zone Water

Groundwater discharge was evaluated in the river adjacent to the Arkema site during the groundwater pilot study (Integral 2005a) using thermal infrared imaging (TIR), the Trident Probe, and the UltraSeep® system. Pressure transducers were deployed in upland wells in the Chlorate Plant area (well MWA-32i) and the Acid Plant area (well MWA-10i) to collect measurements during the UltraSeep® investigation.

TIR Survey

TIR imaging is a distributed groundwater mapping technique that relies on a temperature difference between surface water and groundwater (Integral 2005a). The images produced by the survey have a high resolution, with a ground surface pixel size of 1.5 m^2 and temperature differential increments of 0.2 degrees Celsius.

The TIR survey was conducted in November 2004 when the temperature difference between Willamette River water and groundwater at the Arkema site was approximately 6.9 degrees Celsius. The TIR survey did not positively identify any groundwater

discharge areas at the Arkema site or any other areas surveyed, but it did identify a number of point sources (i.e., known outfalls). The utility of the TIR survey in identifying groundwater seepage areas was limited; the primary but not sole confounding factor was thermal stratification of the river.

Trident Probe Survey

The Trident Probe is a direct-push system equipped with temperature, conductivity, and water sampling probes (Integral 2005a). The Trident Probe operates as a point measurement system that evaluates the contrast in temperature and conductivity between surface water and transition-zone water. Multiple point measurements are combined to develop a qualitative map of groundwater discharge zones. Interpretation of the Trident temperature results requires consideration of tidal influences, sediment texture, and stratigraphy. Because of tidal influences on the system, flux at the sediment-water interface can alternate between positive and negative over the course of each tidal cycle (Integral 2005b).

In November 2004, the Trident Probe was employed to collect temperature and conductivity measurements in river water and shallow sediments along 11 transects (5 in the Acid Plant area and 6 in the Chlorate Plant area). Each transect had three or four individual measurement stations. Station locations in the Acid Plant and Chlorate Plant areas are provided in Appendix B (Figures 2-4 and 2-6).

Temperature differences between surface water and sediments 60 cm below mudline generally increased with distance from the shore. In addition, silty sediments generally displayed greater temperature differences than sandy sediments, likely because tidal mixing effects are reduced in zones of lower hydraulic conductivity. A strong conductivity signal was observed at the site. The high conductivity readings may be associated with groundwater discharge (Integral 2005b).

The single events measured in the Trident study may not represent long-term groundwater seepage, cannot provide data on seasonal variations, and cannot capture alterations between positive and negative flux due to the tidal cycle.

UltraSeep® Survey

The UltraSeep® is an automated seepage meter that uses an ultrasonic flow meter to measure flux as a function of time over the period of deployment. It produces direct quantitative measurements, even at very low seepage rates. The UltraSeep® system can also be fitted with various water quality probes.

The UltraSeep® system was deployed at three locations at the Arkema site: two in the former Acid Plant area (AP04B and AP04D; Figure 2-4 [Appendix B]) and one in the former Chlorate Plant area (CP07B; Figure 2-6 [Appendix B]). Prior to each deployment, the UltraSeep® system was programmed to collect flow records every 5 to 12 minutes (depending on station) for approximately 24 hours. Fifteen-minute groundwater level data were also collected by pressure transducers deployed in two nearshore wells at the site during deployments of the UltraSeep®.

The flow record from each deployment is presented in Appendix B (Figure 2-11), plotted with tidal height and groundwater level readings from the nearshore groundwater wells. The UltraSeep® discharge signals recorded at all three locations show evidence of a periodic semidiurnal wave, indicative of the tidal influence (Integral 2005b). A clear negative correlation between tidal stage and seepage rate was not observed, likely indicating a phase lag between groundwater response in the nearshore area and the resulting effect of changing gradient on the seepage rate (Integral 2005b). A comparison of the tidal and groundwater level data shows a clear groundwater-surface water connection, consistent with the tidal influence study at the site in 1999 (ERM 2004). Furthermore, groundwater head data show asymmetry, with the rise in hydraulic head being more rapid than the subsequent decline. A similar groundwater response has been observed in other discharge studies (Integral 2005b).

At all three UltraSeep® locations, both positive and negative seepage rates were observed. The scale of specific discharge, as measured in all three deployments, indicates low seepage rates, on the order of a few cm/day. The magnitude of both the peak positive and negative seepage rates can be related to sediment texture at each deployment location. The location with the highest discharge (maximum reading 6.11 cm/day) was station CP07B, a sandy area. Station AP04B, a sandy silt area, exhibited the second highest specific discharge (maximum reading 1.97 cm/day). Finally, the lowest discharge (maximum reading 0.47 cm/day; an overall negative value, though many of the measurements were near the limits of detection for the meter) was observed at station AP04D, a fine silt location.

The results of the survey indicate that although the specific discharge rates fluctuate between positive and negative values (i.e., groundwater discharge and recharge, respectively), the magnitude of specific discharge was very small. Because the UltraSeep® data were collected over a short time (i.e., 24 hours per station) at a limited number of stations, the data may not represent long-term seepage rates and do not provide any information on seasonal variations.

3.2.2.2 Deep Sediment Groundwater

During the Stage 1 and 2 investigations, groundwater samples were collected from depths ranging to 37.8 ft below mudline. Relative surface water and groundwater level measurements were collected at each screened interval prior to groundwater sample collection. The results indicate that the potentiometric surface of groundwater in sediments is generally higher than the river level (typical head difference ranged between 0.1 and 1.0 ft). Some of the measurements, however, indicated a potentiometric surface of groundwater in sediments lower than the river level. The surface water potentiometric surface differences should be interpreted carefully because the groundwater levels were measured from temporary monitoring points and water levels may not represent a static equilibrated groundwater surface (Integral 2003). In addition, tidal stages were not correlated with the water levels measured during the Stage 1 and 2 investigations.

3.2.2.3 Upland Groundwater

Groundwater occurs in fill materials and four distinct groundwater zones beneath the site. In general, the depth to groundwater increased from west to east across the site (from Front Avenue toward the Willamette River). Table 3-2 provides a summary of the four groundwater zones and their characteristics (Integral 2004a).

Table 3-2. Upland Groundwater Zones and Characteristics.

Shallow Unconfined Alluvial Aquifer	
No. of Monitoring Wells	>50 (includes wells installed for monitoring of pilot studies)
Depth of Aquifer	Unconfined – ground surface to 32 ft bgs
Depth to First Groundwater	6 to 12 ft on the western portion of the site; 14 to 32 ft on the eastern portion of the site (adjacent to the river)
Saturated Thickness	~20 ft on the western portion of the site; ~10 to 15 ft adjacent to the river
Groundwater Flow Direction	East-northeast in the Acid Plant area; east-southeast in the Chlorate Plant area
Hydraulic Gradient	0.0024 to 0.0069 ft/ft
Hydraulic Conductivity	5.9 to 34 ft/day (17 ft/day average)

Intermediate Confined Alluvial Aquifer	
No. of Monitoring Wells	11
Depth of Aquifer	36-46 ft bgs in the Acid Plant and Chlorate Plant areas
Saturated Thickness	5 to 10 ft
Groundwater Flow Direction	East-northeast in the Acid Plant area; east-southeast in the Chlorate Plant area
Hydraulic Gradient	0.0038 to 0.0069 ft/ft
Hydraulic Conductivity	0.04 ft/day to 21 ft/day (5.8 ft/day average)

Table 3-2. Upland Groundwater Zones and Characteristics.

Deep Confined Alluvial Aquifer	
No. of Monitoring Wells	1
Depth of Aquifer	40-45 ft bgs
Saturated Thickness	Unknown
Groundwater Flow Direction	Assumed to be East-northeast
Hydraulic Gradient	Unknown
Hydraulic Conductivity	0.3 ft/day

Basalt Bedrock Aquifer	
No. of Monitoring Wells	1
Depth of Aquifer	45 to >76 ft bgs (maximum depth explored)
Saturated Thickness	Unknown
Groundwater Flow Direction	Assumed to be Northeast
Hydraulic Gradient	Unknown
Hydraulic Conductivity	Unknown

On the upland portion of the site, vertical hydraulic gradients between groundwater zones are primarily downward, with occasional upward gradients observed for well pairs near the Willamette River. Shallow groundwater at the site is likely recharged by precipitation that infiltrates at and to the west of the site.

The silt horizons (aquitards) separating the groundwater zones vary in thickness from approximately several inches to 5 ft. The distinct groundwater zones have been observed in most parts of the site, with the exception of the southeastern portion. In that area, downgradient of the Chlorate Plant Area, the silt aquitard tends to become discontinuous and the shallow and intermediate groundwater zones tend to coalesce.

The shallow groundwater surface fluctuates seasonally, rising during periods of high rainfall and infiltration and decreasing during mid- to late-summer and low rainfall periods. Shallow groundwater in close proximity to the Willamette River rises in direct response to large increases in Willamette River stage (e.g., during a flood). In general, these short-term perturbations do not affect shallow groundwater flow directions, with the exception of short-term groundwater flow reversals in very close proximity to the river (i.e., the transition zone).

A tidal influence study conducted at the site in February 1999 provided a general understanding of the effects that tidal and river stage fluctuations in the Willamette River have on the groundwater flow system at the site (ERM 2004). The shallow-zone groundwater levels were not affected by the fluctuations in the river, whereas intermediate- and deep-zone groundwater levels exhibited some influence from the Willamette River tidal fluctuations up to 300 ft from the river. Results of the tidal

influence monitoring suggest that Willamette River fluctuations are propagated inland as pressure waves through the intermediate and deep groundwater zones, but do not significantly alter the groundwater flow system at the site.

3.3 ENGINEERING AND PHYSICAL PARAMETERS

Arkema site engineering characteristics are summarized below and are based on information available from previous investigations at the facility (refer to references in Section 3.1). The information includes engineering characteristics of both the upland and the sediment conditions at the Arkema site.

The following list of engineering and physical characteristics were considered in the review of previous investigations:

- Density/consistency
- Liquid limit (LL), plastic limit (PL) and plasticity index (PI)
- Percent moisture
- Organic content
- Gradation
- Porosity
- Consolidation characteristics
- Shear strength and stiffness
- Dynamic (seismic) characteristics.

Data available from previous investigations and data obtained from additional characterization as described in this EE/CA work plan will be used to evaluate the conceptual design of the removal action alternatives and to compare the removal action alternatives.

3.3.1 Available Information

From 1997 to 2004, multiple investigations occurred at the Arkema facility both upland and in-water (refer to Section 3.1). Of the data collected there is limited information regarding physical properties of the soil and sediment for an engineering evaluation. The primary sources for this information are geotechnical borings (direct-push borings and monitoring well installations upland) and sediment investigations (in-water and beach cores and surface grabs). Table 3-3 presents the physical parameter data collected at the Arkema facility and vicinity for upland soils and in-water sediments.

Table 3-3. Summary of Physical Parameters Collected in Upland Soils and In-water Sediments.

Physical Parameter	No. of Samples Collected for Analysis	
	Sediment/Bank	Soil
Grain Size[(a)]	120	14
Specific Gravity[(b)]	70	3
Percent Moisture[(c)]	77	11
Bulk Density	0	3
Hydraulic Conductivity	0	3
Liquid Limit	5	9
Plastic Limit	5	9
Plasticity Index	5	9

Notes
(a) 120 samples from 73 sample locations
(b) 70 samples from 41 sample locations
(c) 77 samples from 48 sample locations

3.3.2 Upland Soil Physical Properties

A number of borings and monitoring wells have been installed at the site as discussed in Section 3.1. Of these, physical property data are available from six locations. The results are presented below in Table 3-4. No data have been collected for upland shear strength or dynamic properties.

Table 3-4. Upland Soil Physical Properties.

Station ID	Sample Interval (ft bgs)	Percent Moisture (%)	Specific Gravity	Bulk Density (lb/ft3)	Dry Density (lb/ft3)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	USCS Soil Class	Hydraulic Cond. (ft/day)
MWA-8i	36.5-37.8	43	--	--	--	38	31	7	ML	--
MWA-8i	48-49	35	--	--	--	NP	NP	NP	SM	--
MWA-9i	30-32	34	--	--	--	NP	NP	NP	SM	--
MWA-9i	38-40	45	--	--	--	43	31	12	ML	--
MWA-10i	30-32	48	--	--	--	39	30	9	ML	--
MWA-10i	36-38	54	--	--	--	42	32	11	ML	--
MWA-10i	44-46	37	--	--	--	37	36	11	ML	--
MWA-10i	45.3-46.8	34.2	2.7	120	96.6	31	25	6	ML	0.0028
MWA-11i	39-40.25	37.2	2.7	119	86.9	41	24	17	CL	0.0007
MWA-12i	48-50	35	--	--	--	41	22	19	CL	--
MWA-13d	48-50	45	2.7	112	76.5	38	39	9	ML	0.0071

Notes:
Bulk density is dry mass/wet volume
NP – not plastic
--not analyzed
Data in table obtained from *Upland RI Lots 3 & 4 and Tract A* (ERM 2004)

Of the above wells, MWA-8i through MWA 10i and MWA-13d are located just upland from the top of the river bank between Docks 1 and 2. Due to their proximity to the bank

it is important to consider the physical parameter data that is available. Based on boring logs, the first 25 ft is fill material followed by a mix of silt and sand layers. The Atterberg limits indicate low (MWA-10i 45.3-46.8) to medium compressibility/plasticity properties for these soils. The bulk density and specific gravity results indicate the analyzed samples are comprised of mostly silts and clays when compared to typical ranges for each of the soil types.

3.3.3 Sediment Physical Properties

Data for physical properties were collected during previous investigations of surface and subsurface sediments. Sediments collected from 1997 to 1998 were analyzed for grain size only (Weston 1998). All sediments collected offshore of the Arkema facility during Portland Harbor RI/FS activities were analyzed for grain size and percent moisture[6] (Integral 2004b, 2005a, b). Of these, 70 samples (41 sample locations) were analyzed for specific gravity and 5 samples (5 locations) were analyzed for LL, PL, and PI. Table 3-5 presents the physical data for the above five sample locations with the most physical data available.

Table 3-5. Physical Data for In-water Sediments.

Station ID	Sample Interval (ft)	Percent Moisture (%)	Specific Gravity	Bulk Density (lb/ft3)	Dry Density (lb/ft3)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Hydraulic Conductivity (ft/day)
LW2-C341	0.984-4.43	49.3	1.45	--	--	--	NP	--	--
LW2-C356-B	0.984-4.46	50.9	1.43	--	--	36.7	31.4	5.3	--
LW2-G349	0-0.919	48	1.46	--	--	59.1	28.4	30.7	--
LW2-G350	0-0.95	49.9	1.45 T	--	--	--	NP	--	--
LW2-G368	0-0.853	59.4	1.44	--	--	38.2	29.9	8.3	--

Notes:
Sample interval is in feet below mudline
--not analyzed
NP – non-plastic
T – The associated numerical number was mathematically derived (e.g. from summing multiple analyte results or calculating the average of multiple results for a single analyte). Also indicates that all results that are selected for reporting in preference to other available results (e.g. for parameters reported by multiple methods) for Round 2 data.
(1) Percent Moisture data is an average value and is from unvalidated data.
Data in table obtained from *Round 2A Sediment Site Characterization Report* (Integral, 2005a)

Atterberg limits indicate a medium to high (G349) compressibility/plasticity. The average percent moisture of all sediment samples collected offshore of Arkema is 36.5 percent (n=77). Grain size data for most sediment samples were described as silty sands (SM) and sandy silts (ML) (Integral 2004a).

[6] Percent moisture was determined by the laboratories as other analyses were completed on the sample.

3.4 HABITAT CHARACTERISTICS

No specific studies on the habitat conditions have been conducted at the Arkema facility. The Portland Harbor RI/FS the Programmatic Work Plan, Appendix B – Ecological Risk Approach (Integral et al., 2004) that was approved by EPA includes a description of the habitat types in the Lower Willamette River. A summary of the habitat types follows.

Within the Portland Harbor study area the river is characterized by a maintained navigation channel and shoreline that has been modified for industrial and commercial uses. Two general habitat types are present in the Lower Willamette River including open-water, and bank and riparian, as described in Table 3-6.

Table 3-6. Habitat Characteristics in the Lower Willamette River.

Habitat Type	Location	Habitats	Impacts to Habitats	Communities Present
Open-water	Main navigation channel [deeper >20 Columbia River Datum (CRD)] and lower channel slopes (<20 CRD)	Unconsolidated sediments (sands and silts	Seasonal and annual variability, navigation impacts, sediment deposition, erosion, bedload transport, and periodic dredging	Stable and unstable environments of heterogeneous infaunal communities controlled by physical regime
	Near shore (beaches and benches) and upper channel slopes	Unconsolidated sediments (sands and silts)	Less temporal variability, influenced by local riverbank morphologies	Well-developed infaunal invertebrate communities
	Developed shoreline	Rock riprap, sheet piles, bulkheads	Limited benthic communities controlled by physical disturbances	More likely epibenthic communities
Bank and Riparian	Bank and upland	Bank is river beach and unclassified fill, upland is industrial	Industrial activities/ human disturbances (transients)	Shorebirds foraging areas on beach, uplands are limited by industrial activities

Notes:
Arkema beach sample collected as part of Round 2 surface sediment and beach sampling. Area was identified as available to shorebirds and a shorebird foraging area (Integral 2005b)

From RM 9.7 to 7.0 the Willamette River is classified as a deposition zone 1. Specifically the river is depositional as it widens and cross-sectional areas increase, the river flow velocities decrease, and the ability of the river to entrain and transport sediment decreases resulting in the deposition of bedload sediment and possibly sediments in suspension. Bottom sediments are organic, methanogenic silts with deep apparent redox potential discontinuities that have been thickened by deposition of oxidized fine-grained sediment (Integral et al. 2004).

3.5 SCREENING LEVEL CRITERIA

This section presents criteria used to select screening benchmarks for evaluating historical data and the RAA boundary in the EE/CA. Screening benchmarks were compiled based

on human health toxicity, ecological toxicity, and natural background conditions on the Willamette River, and available site-specific background concentrations. Sources of benchmarks evaluated for each medium are summarized below.

3.5.1 Surface Water

Screening values for chemicals in Willamette River water were compiled from the Oregon Administrative Rules (OAR) 340-041-0033 (Tables 33a and 33b). The Oregon Environmental Quality Commission adopted the criteria listed in these tables on May 20, 2004 and they became effective February 15, 2005 for the waters of the state. Willamette Basin-specific criteria are listed in OAR 340-041-0340 through -0345.

The acute water quality values were selected as principal threat screening values (PTSVs). USEPA (1991) defines principal threat wastes as source materials that are highly toxic or highly mobile and which cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur. USEPA (1991) does not establish threshold levels of toxicity that equate to a principal threat. However, USEPA (1991) indicates[7] that principal threat levels are identified at or above the high end of the risk range that would result in a risk management action. This general guidance is consistent with development of preliminary remediation goals and the implementation of NTCRA's, which seek to identify principal threat chemicals for migration pathways that should be removed, or intervention measures needed to prevent existing or imminent threats to the environment (DOE 1997a,b).

Table 3-7 lists the screening criteria for Willamette River surface water adjacent to the Arkema site. A number of the screening criteria were calculated based on the hardness, pH, and temperature of Willamette River water adjacent to the site. Field measurements of pH (7.20) and temperature (7.56° Celsius) were taken from a Willamette River water sample collected in February 2003 during the Stage 1 and 2 in-river sediment and groundwater investigation (Integral 2003). A hardness value of 28.8 mg/L was calculated for this sample, using the analytical results for calcium and magnesium ions (7.4 mg/L and 2.5 mg/L, respectively) measured by EPA Method 6010B (see equation in Table 3-7).

3.5.2 Transition-Zone Water

For the Arkema site, ground water has been identified as a secondary source of chemicals that may be transported into near-surface transition-zone water and result in exposure to benthic organisms. Consequently, comparisons with PTSVs (Table 3-7) are intended to

[7] USEPA (1991) states that treatment alternatives should be evaluated for source materials with combined mobility and toxicity that result in 10^{-3} or greater cancer risk for human health.

identify locations where chemical concentrations represent a potential hazard and could benefit from early evaluation and action at the site. The selected PTSVs are not intended to replace toxicity reference values or site-specific remediation goals, both of which may be set at lower concentrations pursuant to a more comprehensive remedial investigation, and human health and ecological risk assessments for the site.

Table 3-7. Water Quality Criteria, Oregon DEQ Tables 33A and 33B.

Compound	CAS Number	Freshwater Acute (µg/L)	Freshwater Chronic (µg/L)
Water Quality Criteria, Oregon DEQ Table 33A			
Aldrin	309002	3	-
Alkalinity		-	20000
BHC gamma- (Lindane)	58899	0.95	0.08
Chlordane	57749	2.4	0.0043
Chloride	16887006	860000	230000
Chlorine	7782505	19	11
Chloropyrifos	2921882	0.083	0.041
Cyanide	57125	22	5.2
4-4'-DDTr (4-4'-DDT+metabolites)		1.1	0.001
Demeton	8065483	-	0.1
Dieldrin	60571	0.24	-
Endosulfan		0.22	0.056
Endosulfan alpha-	959988	0.22	0.056
Endosulfan beta-	33213659	0.22	0.056
Endrin	72208	0.086	-
Guthion	86500	-	0.01
Heptachlor	76488	0.52	0.0038
Heptachlor Epoxide	1024573	0.52	0.0038
Iron	7439896	-	1000
Malathion	121755	-	0.1
Mercury	7439976	2.4	0.012
Methoxychlor	72435	-	0.03
Mirex	2385855	-	0.001
Parathion	56382	0.065	0.013
PCBs	1336363	2	0.014
Pentachlorophenol	87865	10.67 [a]	8.18 [a]
Sulfide-Hydrogen Sulfide	7783064	-	2
Toxaphene	8001352	0.73	0.0002
Water Quality Criteria, Oregon DEQ Table 33B			
Ammonia	7664417	19.73 [a]	5.39 [a]
Arsenic	7440382	340	150

Table 3-7. Water Quality Criteria, Oregon DEQ Tables 33A and 33B.

Compound	CAS Number	Freshwater Acute (µg/L)	Freshwater Chronic (µg/L)
Water Quality Criteria, Oregon DEQ Table 33B			
Cadmium	7440439	0.60 [a]	0.10 [a]
Chromium, trivalent	-	205.56 [a]	26.74 [a]
Chromium, hexavalent	18540299	16	11
Copper	7440508	4.16 [a]	3.09 [a]
Dieldrin	60571	-	0.056
Endrin	72208	-	0.036
Lead	7439921	16.28 [a]	0.63 [a]
Nickel	7440020	163.35 [a]	18.14 [a]
Selenium	7782492	-	5
Silver	7440224	0.38 [a]	0.1
Tributyltin	688733	0.46	0.063
Zinc	7440666	40.81 [a]	41.15 [a]

Notes:
- No screening criteria are listed in Tables 33a or 33b
[a] All calculated values were rounded to two decimal places

Hardness
A hardness value of 28.8 mg/L was used in the calculations of acute and chronic guidance values. The hardness value was calculated from calcium and magnesium ion concentrations using the following formula in *The Geochemistry of Natural Waters* (Drever 1982):

Hardness Equivalent CaCO3 = 2.5(mg/L Ca) + 4.1(mg/L Mg)

Hardness was calculated based on Ca and Mg concentrations (7.4 and 2.5 mg/L, respectively) detected in the Willamette River water sample collected during the Stage 1 and 2 investigation (Integral 2003).

Ammonia: Equations for the presence of salmonids and fish early life stages were used for the water quality criteria calculations. A temperature of 7.56 degrees and a pH value of 7.2 (from Willamette River water sample collected during the Stage 1 and 2 investigation [Integral 2003]) were used for the chronic guidance calculation.
[a] Screening criteria value calculated based on site-specific information

3.5.3 Sediment (Including Bank Soils)

3.5.3.1 Benthic Community Sediment Quality Values.

Screening values for chemicals in river sediments were compiled from sediment quality values (SQVs) published by NOAA (1999), Smith et al. (1996), and MacDonald et al. (2000). Each of these approaches is based on sediment toxicity tests and associated

sediment chemistry values that can be used to establish SQVs representative of effects thresholds for benthic organisms.

NOAA's (1999) SQVs are based on a compilation of marine toxicity tests from which effects-only[8] data were selected to determine two sets of values:

- Effects Range Low (ER-L) concentrations – Defined as the 10th percentile of effects values
- Effects Range Median (ER-M) concentrations – Defined as the 50th percentile of effects values

Smith et al. (1996) used both effects and no-effects data from the freshwater BEDS[9] database to estimate two sets of values:

- Threshold Effect Level (TEL) concentrations – Geometric mean of the 15th percentile of effects data and the 50th percentile of no effects data
- Probable Effect Level (PEL) concentrations – Geometric mean of the 50th percentile of effects data and 85th percentile of no effects data.

MacDonald et al. (2000) reviewed six different approaches[10] to derive consensus based values expressed as:

- Threshold Effect Concentrations (TEC) – Geometric mean of SQVs from other studies that represent concentrations below which effects are not expected to occur
- Probable Effect Concentrations (PEC) – Geometric mean of SQVs from other studies that represent concentrations above which effects are expected to occur more often than not.

These SQVs are provided in Table 3-8. The approach for applying SQVs to screen site sediment data is summarized in Section 3.6.3.

[8] Although NOAA's (1999) database contains sediment samples in which toxicity was present and those in which toxicity was not present, only those in which toxicity was present were used to establish ER-L and ER-M SQVs.

[9] Biological effects database for sediments.

[10] Consensus-based geometric mean values were calculated from previously developed SQVs described by Smith et al. (1996), Persaud et al. (1993), EC and MEQ (1992), Long and Morgan (1991), and USEPA (1996, 1997).

Table 3-8. Sediment Quality Values Representing Threshold and Probable Effects Levels to Benthic Communities.

			Threshold Effects Values				Probable Effects Values			
Chemical Class	**Chemical**	**Units**	**ERL**	**TEL**	**TEC**	**SQV_t[1]**	**ERM**	**PEL**	**PEC**	**SQV_p[2]**
Metals	Arsenic	mg/kg	8.2	5.9	9.79	9.79	70	17	33	33
	Cadmium	mg/kg	1.2	0.596	0.99	0.99	9.6	3.53	4.98	4.98
	Chromium	mg/kg	81	37.3	43.4	43.4	370	90	111	111
	Copper	mg/kg	34	35.7	31.6	31.6	270	197	149	149
	Lead	mg/kg	46.7	35	35.8	35.8	218	91.3	128	128
	Mercury	mg/kg	0.15	0.174	0.18	0.18	0.71	0.486	1.06	1.06
	Nickel	mg/kg	20.9	18	22.7	22.7	51.6	36	48.6	48.6
	Silver	mg/kg	1			1	3.7			3.7
	Zinc	mg/kg	150	123	121	121	410	315	459	459
PAH - Low Mol. Wt.	2-Methylnaphthalene	mg/kg	0.070			0.070	0.670			0.670
	Acenaphthene	mg/kg	0.016			0.016	0.500			0.500
	Acenaphthylene	mg/kg	0.044			0.044	0.640			0.640
	Anthracene	mg/kg	0.0853		0.0572	0.0572	1.100		0.845	0.845
	Fluorene	mg/kg	0.019		0.0774	0.0774	0.540		0.536	0.536
	Naphthalene	mg/kg	0.160		0.176	0.176	2.100		0.561	0.561
	Phenanthrene	mg/kg	0.240	0.419	0.204	0.204	1.500	0.515	1.170	1.170
	Total LPAH	mg/kg	0.552			0.552	3.160			3.160
PAH - High Mol. Wt.	Benz(a)anthracene	mg/kg	0.261	0.0317	0.108	0.108	1.600	0.385	1.050	1.050
	Benzo(a)pyrene	mg/kg	0.430	0.0319	0.150	0.150	1.600	0.782	1.450	1.450
	Chrysene	mg/kg	0.384	0.0571	0.166	0.166	2.800	0.862	1.290	1.290
	Dibenz(a,h)anthracene	mg/kg	0.0634		0.033	0.033	0.260			0.260
	Fluoranthene	mg/kg	0.600	0.111	0.423	0.423	5.100	2.355	2.230	2.230
	Pyrene	mg/kg	0.665	0.053	0.195	0.195	2.600	0.875	1.520	1.520
	Total HPAH	mg/kg	1.700			1.700	9.600			9.600
PAH - Total	Total PAH	mg/kg	4.022		1.610	1.610	44.792		22.800	22.800

Table 3-8. Sediment Quality Values Representing Threshold and Probable Effects Levels to Benthic Communities.

			Threshold Effects Values				Probable Effects Values			
Chemical Class	**Chemical**	**Units**	**ERL**	**TEL**	**TEC**	**SQV_t[1]**	**ERM**	**PEL**	**PEC**	**SQV_p[2]**
Pesticides	4,4'-DDD	mg/kg		0.00354		0.00354		0.00851	0.028	0.028
	4,4'-DDE	mg/kg	0.0022	0.00142		0.00142	0.027	0.00675	0.0313	0.0313
	4,4'-DDT	mg/kg				--			0.0629	0.0629
	Total DDTs	mg/kg	0.00158	0.007	0.00528	0.00528	0.0461	4.450	0.572	0.572
	Chlordane (cis & trans)	mg/kg		0.0045	0.00324	0.00324		0.0089	0.0176	0.0176
	Dieldrin	mg/kg		0.00285	0.0019	0.0019		0.00667	0.0618	0.0618
	Endrin	mg/kg		0.00267	0.00222	0.00222		0.0624	0.207	0.207
	gamma-Hexachlorocyclohexane	mg/kg		0.00094	0.00237	0.00237		0.00138	0.00499	0.00499
	Heptachlor epoxide	mg/kg		0.0006	0.00247	0.00247		0.00274	0.016	0.016
Polychlorinated biphenyls	Total PCBs	mg/kg	0.0227	0.0341	0.0598	0.0598	0.180	0.277	0.676	0.676

Notes:

[1] The TEC is selected as the SQV_t. If there is no developed TEC value then the minimum of the ER-L and the TEL is selected.

[2] The PEC is selected as the SQV_p. If there is no developed PEC value then the minimum of the ER-M and the PEL is selected.

Reference: ER-L and ER-M (NOAA 1999), TEL and PEL (Smith et al. 1996), TEC and PEC (MacDonald et al. 2000).

3.5.3.2 Wildlife Sediment Quality Values

EPA (http://www.epa.gov/pbt/background.htm) has identified 12 priority chemicals or compound groups that are persistent, bioaccumulative, and toxic (PBT). These are alkyl-lead, mercury and its compounds, benzo(a)pyrene, dioxins and furans, hexachlorobenzene, octachlorostyrene, PCBs, aldrin/dieldrin, chlordane, mirex, toxaphene, and DDT and its metabolites.

Published screening level criteria are available for selected wildlife species for a few of these substances through the Department of Energy's Oak Ridge National Laboratory (http://risk.lsd.ornl.gov/index.shtml). However, these values are typically based on receptors, complex food web models and exposure assumptions that are specific to the regions in which they were generated and may not be applicable to either Portland Harbor or the Arkema site.

The general procedure for estimating sediment-related dose and therefore sediment screening levels appropriate to semiaquatic birds and mammals is well known and has been incorporated into the programmatic work plan for the Portland Harbor RI/FS (Windward 2004). However, two constraints on this approach make it infeasible to develop sediment screening criteria at this time for the Arkema site. First, the preliminary risk evaluation (PRE) for Portland Harbor is in the draft stages of development and assumptions concerning wildlife exposure to sediments have not been finalized or published in a citable form. Second, assumptions developed for the PRE will be broadly based for harbor-wide use and may not be appropriate for the more limited and site-specific conditions at the Arkema site.

Because of these limitations, it is recommended that selection of wildlife screening values for PBT chemicals be delayed until the PRE for Portland Harbor is published and can provide a stable point of departure for their development and application at the Arkema site. The exposure factors and parameters that will be used to develop sediment screening values for wildlife receptors appropriate to the Arkema site are presented in Appendix C. The equation used to calculate risk and to estimate sediment screening levels is:

$$HQ_j = \frac{\{[S_j \times P_s \times AF_{sj}] + \sum_{Ni=1} [B_{ij} \times P_i \times AF_{ij}]\} \times \frac{FIR}{BW} \times AUF}{TRV_j}$$

where:

HQj = Hazard quotient for contaminant (j) (unitless),

Sj = Contaminant concentration for contaminant (j) in sediment (mg/kg dry weight),

Ps = Sediment ingestion as proportion of diet (unitless)[11],

Ni = Number of different biota types in diet (unitless),

Bij = Contaminant concentration (j) in biota type (i) (mg/kg wet weight),

Pi = Proportion of biota type (i) in diet (unitless),

FIR = Food ingestion rate (kg food [wet weight]/ d),

AFij = Absorbed fraction of contaminant (j) from biota type (i) (unitless),

AFsj = Absorbed fraction of contaminant (j) from sediment (s) (unitless),

TRVj = Toxicity reference value (mg/kg BW/day),

AUF = Area use factor (unitless).

Early resolution of site-related assumptions that affect these parameters will facilitate development of wildlife sediment screening values that are generally consistent with the current harbor-wide approach (in progress). It is therefore recommended that calculation of screening values protective of wildlife exposure via consumption of aquatic organisms be completed upon final publication and approval by EPA of the harbor-wide approach, if it becomes available before completion of the EE/CA report. This approach is consistent with previously stated agency policy (DEQ 2003).

3.5.3.3 Human Health Screening Values

The AOC requests identification of sediment screening values that would be protective of human health via several pathways:

- Direct exposure via consumption of riverbank soils or sediments
- Indirect exposure via consumption of surface water or aquatic organisms

An overview of the methods or limitations to each is provided below.

Direct Exposure to Riverbank Soils and Sediments

As an initial health-protective approach, the most current EPA Region 9 preliminary remediation goals (PRGs) for soil have been proposed as the basis for screening values for beach sediments for Portland Harbor (Kennedy/Jenks 2004a). Although conservative, these screening values do not represent either the sediment and riverbank exposure

[11] The absolute sediment ingestion rate (kg [dry weight]/day) is expressed as the product of Ps × FIR, which is obtained when the equation is expanded.

matrixes or the specific exposure scenarios selected to manage Portland Harbor sediments. Consequently, sediment and riverbank screening values developed for this EE/CA are based on initial Portland Harbor-specific site assumptions and exposure models described in the Programmatic Work Plan and its supporting documentation (Kennedy/Jenks 2004a,b).

Using the reasonable maximum exposure (RME)[12] assumptions and exposure equations provided by Kennedy/Jenks (2004a), sediment screening levels were calculated for each of the seven scenarios[13] that include chemical exposure via direct ingestion of sediments and direct skin contact with sediments. This approach is conservative because it integrates both ingestion and skin contact exposure routes as described in the programmatic work plan, yielding screening values that are lower than those based solely on one exposure route.

Screening values were calculated separately for carcinogens and non-carcinogens. For carcinogens, screening values for the combined ingestion and skin contact routes were determined using:

$$SSV_c = \frac{RL_c \times BW \times AT}{CSF \times EF \times ED \times CF \times (SIR + SA \times AF \times ABS)}$$

where:

SSV_c = Sediment screening value for carcinogens (mg/kg dry weight),

RL_c = Assumed cancer risk level (10^{-5}) (unitless),

BW = Body weight (kg),

AT = Averaging time (days),

CSF = Cancer slope factor $(mg/kg\ BW\text{-}d)^{-1}$,

EF = Exposure frequency (days),

ED = Exposure duration (years),

CF = Conversion factor (kg/mg),

SIR = Sediment ingestion rate (mg/day),

SA = Skin surface area (cm^2/day),

AF = Skin adherence factor (mg/cm^2),

ABS = Skin absorption factor (unitless).

[12] Reasonable maximum exposure.

[13] Dockside Worker, Transients, Recreational Beach User (adult), Recreational Beach User (child), Recreational Fisher, Native American Fisher, Non-tribal Fisher.

For noncarcinogens, screening values for the combined ingestion and skin contact routes were determined from:

$$SSV_{nc} = \frac{RL_{nc} \times RFD \times BW \times AT}{EF \times ED \times CF \times (SIR + SA \times AF \times ABS)}$$

where:

SSV_{nc}= Sediment screening concentration for noncarcinogens (mg/kg dry weight)

HL_{nc} = Assumed non-cancer hazard quotient (1)

RFD = Reference dose (mg/kg BW-d),

and the other parameters defined above. The CSF and RFD values in the above expressions are the same as those summarized by Kennedy/Jenks (2004b). Upper-bound levels for cancer risks (10^{-5}) and non-cancer hazard quotients (1) were assumed to calculate principal threat screening values (PTSVs) for sediments. These risk levels were assumed rather than *de minimis* values because principal threat levels are identified at or above the high end of the risk range that would result in a risk management action (USEPA 1991, DOE 1997a,b).

Sediment screening values calculated for the various exposure scenarios are summarized in Appendix C. Sediment screening values selected for identification of chemicals of potential concern based on this methodology are summarized below in Section 3.6.3.

Indirect Exposure to Sediments via Water and Aquatic Organisms

Sediment screening values do not reflect indirect exposure to sediment via contact with water and ingestion of aquatic organisms. Indirect exposure to sediments via consumption of surface water is not evaluated because the site-related content of sediment particulate matter or sediment porewater in surface water is not known and cannot be predicted with reasonable certainty from the exposure models and scenarios developed for Portland Harbor.

Indirect exposure to sediments via consumption of fish and shellfish is not evaluated. A survey of chemical concentrations in fish and shellfish tissues has been conducted to assess exposure point concentrations for various species site-wide, by river mile, and within fishing zones (Kennedy/Jenks 2004c). However, quantitative relationships[14] between chemical concentrations in fish or shellfish and sediments are in the draft stage of development and have not been finalized or published in a citable form. Such relationships are important because they provide a means of relating sediment

[14] Statistically based correlations and linear regression models supplemented by mechanistic modeling or empirical biota-sediment accumulation factors (Kennedy/Jenks 2004c).

management decisions directly to affected fish and shellfish and indirectly to their human and nonhuman consumers. Once these relationships have been established for the harbor-wide evaluation, they will provide a basis for development of risk-based screening criteria for sediments. It is therefore recommended that selection of sediment screening values protective of indirect human exposure via consumption of aquatic organisms be completed upon final publication and approval by EPA of the harbor-wide approach, if it becomes available before completion of the EE/CA report. This approach is consistent with previously stated agency policy (DEQ 2003).

3.6 DATA SCREENING

This section summarizes the degree to which detected concentrations exceed the thresholds presented in Section 3.5 for each medium. Raw analytical data have been assembled from historical reports into the Integral database for this project. The magnitude by which detected concentrations exceed screening levels is presented for each medium in Tables 3-9 through 3-10, and 3-12. The tables provide statistical summaries of the data (e.g., minimum, maximum, maximum location, screening criterion, number of chemicals above screening levels). A complete list of all chemicals above screening levels, including concentration/screening factors (C/S-Fs) for each medium are presented in Appendix D.

3.6.1 Surface Water

Data from one surface water sample collected from the platform beneath Dock 2 in the Willamette River during the Stage 2 investigation (Integral 2003) was screened against the Oregon DEQ acute screening criteria (Table 3-7). The sample did not have any analytes that exceeded the acute screening criteria.

3.6.2 Transition-Zone Water

Data from a total of 45 transition-zone water samples collected adjacent to the Arkema site were screened against the Oregon DEQ acute screening criteria (Table 3-7). These samples represent data from a total of ten sample stations. Concentrations above screening criteria were found for one analyte (chloride) and one analyte group (DDTr). Table 3-9 presents a complete list of chemicals above screening criteria, including C/S-Fs, in transition-zone water samples collected adjacent to the Arkema site. Groundwater samples collected during the Stage 1 and 2 Investigation (i.e., WB stations) were not screened because they represent deeper groundwater that is not in contact with ecological or human receptors.

All of the samples screened were from the Portland Harbor Superfund groundwater pathway assessment pilot study (Integral 2005a). During this study a number of different sampling techniques were evaluated at the same stations. As a result, many of the chemicals above acute screening criteria are from samples collected from the same location using different sampling methods. The different sampling methods employed during the pilot study had varying degrees of reliability.

Samples from a total of 8 stations were above the acute screening criteria for chloride. These stations were generally located between Dock 1 and the Salt Dock, with two stations between Docks 1 and 2.

Samples from two stations were minimally above the criteria for DDTr. These samples were collected between Docks 1 and 2. These samples included an unfiltered groundwater sample and its field duplicate, and an unfiltered porewater sample. The two unfiltered transition-zone water samples were collected with the Trident probe and likely overestimated the DDTr concentrations because the sampling process introduces turbidity into the water sample. Filtered transition-zone samples were also collected from this station using the Trident probe; these samples were not above the acute screening criteria for DDTr. The unfiltered porewater sample was collected using a large volume pore water sampler ("peeper"). Sediment can be introduced into the large porewater sampler either through the relatively coarse membrane or through wrinkles at the edges of the membranes.

Table 3-9. Transition-zone Water Sample Concentrations Above Oregon DEQ Acute Screening Criteria.

Station	Sampling Method	Upper Depth	Lower Depth		Sample Date	Analyte	Concentration (mg/L)		Acute Criteria (mg/L)	C/S-F
AP03B-1	Trident (F, FR)				11/19/2004	Chloride	1300		860	1.51
	Trident (F)				11/19/2004	Chloride	3040		860	3.53
	Trident (U, FR)				11/19/2004	DDTr	0.00161	T	0.0011	1.46
	Trident (U)				11/19/2004	DDTr	0.00242	T	0.0011	2.20
AP04B	Trident (F)				11/19/2004	Chloride	2370		860	2.76
	Large Volume Peeper (U)				1/11/2005	DDTr	0.00141	T	0.0011	1.28
AP04D	Trident (F)				11/19/2004	Chloride	1150		860	1.34
CP06C	Trident (F)				11/20/2004	Chloride	34600		860	40.23
	Trident (U)				11/20/2004	Chloride	30600		860	35.58
	Power Grab (F)	0	0.98	ft	1/18/2005	Chloride	4870		860	5.66

Table 3-9. Transition-zone Water Sample Concentrations Exceeding Oregon DEQ Acute Screening Criteria.

Station	Sampling Method	Upper Depth	Lower Depth		Sample Date	Analyte	Concentration (mg/L)		Acute Criteria (mg/L)	C/S-F
CP07B	Trident (F)				11/21/2004	Chloride	10800		860	12.56
	Trident (U)				11/21/2004	Chloride	11300		860	13.14
	Trident (F, FR)				11/20/2004	Chloride	6580		860	7.65
	Trident (U, FR)				11/20/2004	Chloride	9090		860	10.57
	Trident (F)				11/20/2004	Chloride	8980		860	10.44
	Trident (U)				11/20/2004	Chloride	8370		860	9.73
	Ultra Seep (U)				11/22/2004	Chloride	960		860	1.12
	Power Grab (F)	0	0.98	ft	1/18/2005	Chloride	7590	T	860	8.83
CP08D-1	Trident (F)				11/20/2004	Chloride	89700		860	104.30
	Trident (U)				11/20/2004	Chloride	88500		860	102.91
	Power Grab (F)	0	0.98	ft	1/18/2005	Chloride	15500		860	18.02
CP08D-2	Power Grab (F, FR)	0	0.98	ft	1/18/2005	Chloride	24600		860	28.60
CP10A	Trident (F)				11/21/2004	Chloride	32000		860	37.21
	Trident (U)				11/21/2004	Chloride	35600		860	41.40

Notes:
U – Unfiltered
F – Filtered
FR – Field Replicate
DDTr - Sum of 4,4'-DDD, DDE, DDT
C/S-F – Concentration/screening factor

3.6.3 Sediment (includes Bank Soils)

Sediment samples collected from previous investigations in the vicinity of Arkema were compared to benthic community and human-health direct contact screening values. The results are described in the following sections and tables. A complete list of all chemicals above screening levels and C/S-Fs for sediments is presented in Appendix D.

3.6.3.1 Benthic Community Screening

MacDonald et al.'s (2000) consensus-based approach incorporates SQVs established by both NOAA (1999) and Smith et al. (1996) as well as those from several other studies. Thus, the consensus-based values represent a robust compilation of the available SQVs based on a variety of methodological frameworks and benthic ecological settings.

Consequently, only MacDonald et al.'s (2000) consensus based values will be used to screen the site data (PEC and TEC). The other SQVs will be used as a frame of reference for comparisons to the consensus-based values.

Data from a total of 185 sediment samples were available for comparison to screening levels; these data were generated as part of several historical investigations discussed above. Nineteen analytes or analyte groups (e.g., total DDTr) were detected at concentrations above the corresponding PEC for one or more samples. The following analyte classes were above corresponding PEC values (number of individual analytes indicated in parentheses): PCBs (1 - Aroclors), metals (2), chlorinated pesticides (6), and PAHs (10). Table 3-10 presents the summary statistics for chemicals above PEC values in sediment samples previously collected in the vicinity of the Arkema site.

4,4'-DDT and metabolites were the most common chemicals observed above screening levels in sediment samples, especially in sediments between Docks 1 and 2 (e.g., Stations WB-9 and WB-11). The frequency of all other detected chemicals above screening levels was below 10 percent. Figures 3-5 through 3-7 present a comparison of total DDTr concentrations in sediments to corresponding PEC and TEC values. Figures 3-8 through 3-10 present a comparison of total chromium concentrations in sediments to the TEC values (no sediments exceeded the PEC value for total chromium).

3.6.3.2 Human Exposure via Riverbank Soils, Sediments, Water, and Aquatic Organisms

Based on the assumptions provided by Kennedy/Jenks (2004a), the lowest sediment screening values are those representing the Native American fishers and child recreational beach user scenarios (Appendix C). However, the Arkema site is an industrial setting with restricted access and provides a relatively small usable area for the respective activities (e.g., fishing and recreation). The Dockside Worker and Transient scenarios are appropriate for the existing and future site use of the Arkema facility. Consequently, the lower of the screening values for the Dockside Worker or the Transient scenarios was selected for identification of chemicals of potential concern for the EE/CA (Table 3-11).

Data from a total of 185 sediment samples were available for comparison to selected screening levels in Table 3-11. Only aluminum and thallium (12 sample results each), 4,4'-DDD (4), 4,4'-DDT (3), benzo(a)pyrene (2), and aldrin (1) were detected in sediments above corresponding human-health direct contact screening values (Table 3-12 and Appendix D). Aluminum is only slightly above its corresponding SSV in sediments (refer to Table D-2). Aluminum, thallium, and aldrin are not associated with known historical activities on the Arkema site. DDTr was above the corresponding SSV in subsurface sediments located between Docks 1 and 2 (e.g., WB-9 and WB-11).

Table 3-10. Summary statistics associated with chemicals above PEC screening values in sediments (mg/kg) in the vicinity of Arkema.

Parameter	N	Number of Detects	Frequency of Detection	PEC	Number of Detected Chemicals above PECs	Frequency of Chemicals above PECs	Minimum of Detected Chemicals above PECs		Maximum of Detected Chemicals above PECs		Location of Maximum	Sample Interval (FT)			
4,4'-DDD	185	170	91.89%	0.028	120	64.86%	0.0283	NJ	690		WB-11	12.5	-	14.5	ft
4,4'-DDE	185	146	78.92%	0.0313	75	40.54%	0.032		24		WB-9	8	-	10	ft
4,4'-DDT	182	171	93.96%	0.0629	118	64.84%	0.064		4500		WB-9	8	-	10	ft
Total of 4,4'-DDD, DDE, DDT	185	181	97.84%	0.572	85	45.95%	0.58	JT	4760	T	WB-9	8	-	10	ft
Anthracene	132	110	83.33%	0.845	2	1.52%	0.87		1.1		G355	0	-	0.89	ft
Benz(a)anthracene	132	128	96.97%	1.05	6	4.55%	1.08	T	16		G355	0	-	0.89	ft
Benzo(a)pyrene	132	127	96.21%	1.45	4	3.03%	1.6		12		G355	0	-	0.89	ft
Chrysene	132	128	96.97%	1.29	8	6.06%	1.6		19		G355	0	-	0.89	ft
Fluoranthene	132	129	97.73%	2.23	9	6.82%	2.4		23		OSS-004	0.98	-	1.64	ft
Fluorene	132	106	80.30%	0.536	5	3.79%	0.57		0.93		C348	5.02	-	7.87	ft
gamma-Hexachlorocyclohexane	171	23	13.45%	0.00499	11	6.43%	0.0052	NJT	0.43		07R006	0	-	0.49	ft
Heptachlor epoxide	170	3	1.76%	0.016	2	1.18%	0.089		0.11		WB-11	0	-	2	ft
Lead	106	106	100.00%	128	3	2.83%	186		1290	J	G355	0	-	0.89	ft
Naphthalene	141	77	54.61%	0.561	3	2.13%	0.59		1.1		SD92	0	-	2.95	ft
Nickel	106	106	100.00%	48.6	5	4.72%	50.4		716		C356	4.46	-	8.4	ft
Phenanthrene	132	121	91.67%	1.17	10	7.58%	1.3		15		OSS-004	0.98	-	1.64	ft
Pyrene	132	129	97.73%	1.52	13	9.85%	1.6		18		OSS-004	0.98	-	1.64	ft
Total PAHs	132	132	100.00%	22.8	4	3.03%	54.1	T	149	JT	G355	0	-	0.89	ft
Total PCBs	81	41	50.62%	0.676	1	1.23%	0.837	JT	0.837	JT	C366-1	13.8	-	15.2	ft

Table 3-11. Selected Human-Health Sediment Screening Concentrations (mg/kg dw) Based on the Lower of the Dockside Worker or the Transient Scenarios for Direct Exposure Via Sediment Ingestion or Skin Contact.

			Cancer SSVs		Non-Cancer SSVs		
Chemical Group	**CAS**	**Chemical**	**Dockside Worker**	**Transients**	**Dockside Worker**	**Transients**	**Selected SSV**
Butyltin	78763-54-9	Butyltin ion	--	-- [1]	2971	183	183
Butyltin	14488-53-0	Dibutyltin ion	--	--	2971	183	183
Butyltin	1461-25-2	Tetrabutyltin	--	--	178	11	11
Butyltin	36643-28-4	Tributyltin ion	--	--	178	11	11
Dioxin		Total Dioxin TEQ	4.3E-04	6.5E-05	--	--	4.3E-04
Metal	7429-90-5	Aluminum	--	--	594,186	36,649	36,649
Metal	7440-36-0	Antimony	--	--	238	15	15
Metal	7440-38-2	Arsenic	43	65	697	84	43
Metal	7440-43-9	Cadmium	--	--	2,547	347	347
Metal	16065-83-1	Chromium, trivalent	--	--	891,279	54,974	54,974
Metal	18540-29-9	Chromium, hexavalent	--	--	1,783	110	110
Metal	7440-50-8	Copper	--	--	23,767	1,466	1,466
Metal	7439-92-1	Lead	--	--	--	--	--
Metal	7439-96-5	Manganese	--	--	83,186	5,131	5,131
Metal	7439-97-6	Mercury (tissue)	--	--	59	4	4
Metal	7439-97-6	Mercury (sediment)	--	--	178	11	11
Metal	7440-02-0	Nickel	--	--	11,884	733	733
Metal	7782-49-2	Selenium	--	--	2,971	183	183
Metal	7440-22-4	Silver	--	--	2,971	183	183
Metal	7440-28-0	Thallium	--	--	39	2	2
Metal	7440-66-6	Zinc	--	--	178,256	10,995	10,995
PAH	91-57-6	2-Methylnaphthalene	--	--	7,152	663	663
PAH	83-32-9	Acenaphthene	--	--	107,278	9,946	9,946
PAH	208-96-8	Acenaphthylene	--	--	107,278	9,946	9,946
PAH	120-12-7	Anthracene	--	--	536,389	49,728	49,728
PAH	56-55-3	Benz(a)anthracene	69	79	--	--	69

Table 3-11. Selected Human-Health Sediment Screening Concentrations (mg/kg dw) Based on the Lower of the Dockside Worker or the Transient Scenarios for Direct Exposure Via Sediment Ingestion or Skin Contact.

			Cancer SSVs		Non-Cancer SSVs		
Chemical Group	**CAS**	**Chemical**	**Dockside Worker**	**Transients**	**Dockside Worker**	**Transients**	**Selected SSV**
PAH	50-32-8	Benzo(a)pyrene	6.858	7.947	--	--	6.858
PAH	205-99-2	Benzo(b)fluoranthene	69	79	--	--	69
PAH	191-24-2	Benzo(g,h,i)perylene	--	--	53,639	4,973	4,973
PAH	207-08-9	Benzo(k)fluoranthene	686	795	--	--	686
PAH	218-01-9	Chrysene	6,858	7,947	--	--	6,858
PAH	53-70-3	Dibenz(a,h)anthracene	6.858	7.947	--	--	6.858
PAH	206-44-0	Fluoranthene	--	--	71,519	6,630	6,630
PAH	86-73-7	Fluorene	--	--	71,519	6,630	6,630
PAH	193-39-5	Indeno(1,2,3-cd)pyrene	69	79	--	--	69
PAH	91-20-3	Naphthalene	--	--	35,759	3,315	3,315
PAH	85-01-8	Phenanthrene	--	--	53,639	4,973	4,973
PAH	129-00-0	Pyrene	--	--	53,639	4,973	4,973
PCBs	1336-36-3	Total PCB Aroclors	24	28	35	3	3
PCBs		Total PCB Congeners	--	--	35	3	3
PCBs		Total PCB Congeners, adjusted	24	28	--	--	3
PCBs		Total PCB TEQ	3.3E-04	3.7E-04	--	--	3.3E-04
Pesticide	309-00-2	Aldrin	0.979	0.755	18	1	0.755
Pesticide	319-84-6	alpha-Hexachlorocyclohexane	2.641	2.036	4,753	293	2.036
Pesticide	319-85-7	beta-Hexachlorocyclohexane	9.243	7.126	357	22	7.126
Pesticide	319-86-8	delta-Hexachlorcyclohexane	--	--	--	--	--
Pesticide	60-57-1	Dieldrin	1.040	0.802	30	2	0.802
Pesticide	72-20-8	Endrin	--	--	178	11	11
Pesticide	7421-93-4	Endrin aldehyde	--	--	178	11	11
Pesticide	53494-70-5	Endrin ketone	--	--	178	11	11
Pesticide	58-89-9	gamma-Hexachlorocyclohexane	49	70	677	78	49
Pesticide	76-44-8	Heptachlor	3.697	2.850	297	18	2.850

Table 3-11. Selected Human-Health Sediment Screening Concentrations (mg/kg dw) Based on the Lower of the Dockside Worker or the Transient Scenarios for Direct Exposure Via Sediment Ingestion or Skin Contact.

			Cancer SSVs		Non-Cancer SSVs		
Chemical Group	**CAS**	**Chemical**	**Dockside Worker**	**Transients**	**Dockside Worker**	**Transients**	**Selected SSV**
Pesticide	1024-57-3	Heptachlor epoxide	1.828	1.410	8	0.476	0.476
Pesticide	72-43-5	Methoxychlor	--	--	2971	183	183
Pesticide	8001-35-2	Toxaphene	15	12	594	37	12
Pest - Chlor	5103-71-9	alpha-Chlordane	--	--	--	--	--
Pest - Chlor	27304-13-8	Oxychlordane	--	--	--	--	--
Pest - Chlor	12789-03-6	Total Chlordane	181	261	1,129	130	130
Pest - Chlor	5103-74-2	trans-Chlordane	--	--	--	--	--
Pest - Chlor	39765-80-5	trans-Nonachlor	--	--	--	--	--
Pest - DDD	53-19-0	2,4'-DDD	--	--	--	--	--
Pest - DDD	72-54-8	4,4'-DDD	--	--	--	--	--
Pest - DDD		Total DDD	271	406	1162	139	139
Pest - DDE	72-55-9	4,4'-DDE	--	--	--	--	--
Pest - DDE		Total DDE	191	287	1162	139	139
Pest - DDT	789-02-6	2,4'-DDT	--	--	--	--	--
Pest - DDT	50-29-3	4,4'-DDT	--	--	--	--	--
Pest - DDT		Total DDT	191	287	1,162	139	139
Pest - Endo	959-98-8	alpha-Endosulfan	--	--	--	--	--
Pest - Endo	33213-65-9	beta-Endosulfan	--	--	--	--	--
Pest - Endo	1031-07-8	Endosulfan sulfate	--	--	--	--	--

Table 3-11. Selected Human-Health Sediment Screening Concentrations (mg/kg dw) Based on the Lower of the Dockside Worker or the Transient Scenarios for Direct Exposure Via Sediment Ingestion or Skin Contact.

			Cancer SSVs		Non-Cancer SSVs		
Chemical Group	**CAS**	**Chemical**	**Dockside Worker**	**Transients**	**Dockside Worker**	**Transients**	**Selected SSV**
Pest - Endo	115-29-7	Total Endosulfan	--	--	3,565	220	220
Phenol	106-44-5	4-Methylphenol	--	--	29,709	1,832	1,832
Phenol	87-86-5	Pentachlorophenol	327	325	42,000	3,347	325
Phenol	108-95-2	Phenol	--	--	178,256	10,995	10,995
Phthalate	117-81-7	Bis(2-ethylhexyl) phthalate	1,188	916	11,884	733	733
Phthalate	85-68-7	Butylbenzyl phthalate	--	--	118,837	7,330	7,330
Phthalate	84-66-2	Diethyl phthalate	--	--	475,349	29,319	29,319
Phthalate	84-74-2	Dibutyl phthalate	--	--	59,419	3,665	3,665
Phthalate	117-84-0	Di-n-octyl phthalate	--	--	23,767	1,466	1,466
SVOC	86-74-8	Carbazole	2,689	3,302	--	--	2,689
SVOC	132-64-9	Dibenzofuran	13,447	16,509	--	--	13,447
SVOC	118-74-1	Hexachlorobenzene	34	41	1,537	151	34
SVOC	87-68-3	Hexachlorobutadiene	690	847	384	38	38
SVOC	67-72-1	Hexachloroethane	3,842	4,717	1,921	189	189

[1]-- Data not avalable (Kennedy/Jenks 2004b).

Table 3-12. Summary statistics associated with chemicals above the selected SSV in sediments (mg/kg) off Arkema.

Parameter	N	Number of Detects	Frequency of Detection	Selected SSV	Number of Detected Chemicals above SSVs	Frequency of Chemicals above SSVs	Minimum of Detected Chemicals above SSVs	Maximum of Detected Chemicals above SSVs	Location of Maximum	Sample Interval (FT)
4,4'-DDD	185	170	91.89%	139	4	2.16%	240	690	WB-11	12.5 - 14.5 ft
4,4'-DDT	182	171	93.96%	139	3	1.65%	920	4500	WB-9	8 - 10 ft
Aldrin	171	44	25.73%	0.755	1	0.58%	1.34 J	1.34 J	C356	4.462 - 8.399 ft
Aluminum	106	106	100.00%	36649	12	11.32%	37500	42700	SD93	0 - 0.3281 ft
Benzo(a)pyrene	132	127	96.21%	6.858	2	1.52%	9.6	12	G355	0 - 0.8858 ft
Thallium	19	12	63.16%	2	12	63.16%	4	15	SD93	0 - 0.3281 ft

4.0 PRELIMINARY CONCEPTUAL SITE MODEL

At this phase of the EE/CA, the conceptual site model (CSM) presents a preliminary understanding of site conditions. Integral developed the CSM from the information presented in Section 3 and general knowledge of site conditions and chemical transport behavior (Integral 2004a). Development of a CSM early in the EE/CA process helps identify data gaps and guides collection of data appropriate for assessing risks and remedial actions. The CSM will be refined throughout the project as additional data are collected and site conditions are better understood. The CSM, illustrated in Figures 4-1 and 4-2 and described in the following sections, includes sources of chemicals (primary and secondary), transport pathways, and potential exposure pathways for human and ecological receptors.

4.1 SOURCES

Constituents of interest in environmental media at the site are primarily associated with site manufacturing process residue, including DDT and its metabolites DDD and DDE, monochlorobenzene (MCB, or chlorobenzene), perchlorate, and hexavalent chromium (Integral 2005)[15]. This section presents information describing how various activities and operations that took place at the Arkema facility may have been sources (primary and secondary) of these chemicals to the Willamette River (from Integral and GSI 2004, Integral 2005, USEPA 2005).

4.1.1 Primary Sources

The following list of the primary sources of COIs from the Arkema site was summarized from the draft CSM for the Arkema facility (Integral 2004a, with comments from USEPA 2005) and as shown on Figure 4-3. Because the site has undergone extensive remediation and demolition to date, including interim remedial source control measures, many of these areas may no longer function as sources of COIs to the in-water portion of the site.

- Former Storm Sewer Outfall - In 1947 at the initiation of DDT manufacturing, MPR was discharged to floor drains connected to a storm sewer that drained into the Willamette River. The suspected outfall location that received the MPR is located between Docks 1 and 2, near boring location WB-9 (Figure 4-3).

[15] pH variations and salinity gradients in sediments and groundwater are also of interest as described in the AOC SOW.

- Former MPR Pond – A shallow unlined pond was constructed in 1948 northeast of the manufacturing building to receive MPR and was used until about 1954 when DDT manufacturing operations ceased. Major portions of the former MPR pond soils were removed during a soil IRM in 2000.
- Former MPR Trench - In 1951 or 1952, a trench 8 ft wide by 285 ft long was constructed north of the MPR pond to increase its capacity. Use of the MPR trench ceased in about 1954 when DDT operations ended. Elevated concentrations of MCB and DDT were found in this area prior to soil removal. A two-phased soil removal and source control interim remedial measure was implemented in 2000 and 2001. Impacted soil was removed in portions of the Acid Plant Area to depths of up to 12 ft bgs.
- Former DDT Process Building – The pesticide DDT was manufactured in the former DDT process building from 1947 to 1954. Chemical base stocks used in the DDT manufacturing process included MCB, chloral, and sulfuric acid. Some DDT handling took place in Warehouse No. 2, in the northwest corner of the Acid Plant area. From 1958 to 1962, after DDT manufacturing ceased ammonium perchlorate operations were conducted in the former DDT process building. During this period, sodium perchlorate was produced inside the chlorate cell room. Sodium perchlorate was transferred to the Acid Plant Area where it was converted to ammonium perchlorate by using ammonium chloride to form a solid propellant for guided missiles. The production of sodium perchlorate and ammonium perchlorate ceased in 1962.
- Sodium Chlorate Manufacturing - Sodium chlorate manufacturing started in the Chlorate Plant Area in 1941. Chlorate solutions were shipped by truck or barge. Trucks were loaded on the southern side of the Chlorate Plant Area. Barges were loaded at Dock 2. The production of sodium perchlorate in the chlorate plant is the source of the main perchlorate plume (USEPA 2005).
- Lot No. 1 Former DDT Trench – Historical construction activities in the Acid Plant area generated soils with DDT residues that were reportedly disposed of in a defined trench on Lot No. 1 of the site. Arkema discovered and excavated the trench on Lot 1 that contained DDT MPR in 1994. Confirmation samples indicated low concentrations of DDT, DDD, and DDE (below DEQ industrial soil cleanup levels) are present in shallow soil in a discrete area between 3 and 14 ft bgs around the perimeter of the former trench. None of the 33 confirmation samples contained constituent pesticides greater than the USEPA Region 9 Preliminary Remediation Goal (PRG) for industrial soil. Arkema has a DEQ-approved soil management plan to ensure proper management of these soils.
- Riverbank Soil – Fill was placed in the Acid Plant Area bordering the Willamette River after DDT manufacturing ceased. It appears that the bank adjacent to the

Acid Plant Area has been filled out toward the Willamette River approximately 200 ft since the 1950s(CH2M Hill 1997). Fill thickness ranges from a few feet in the former DDT manufacturing area to approximately 25 ft along the riverbank (Integral and GSI 2004). DDT residuals have been measured in some portions of the fill and have been addressed as part of the ongoing IRMs for the upland portion of the Arkema site.

- Historical Spills - Chemical spills when the plant was operational included a 1,200-gallon ammonium hydroxide leak to the sewer system in 1986, a sodium chlorate release of unknown quantity to the sewer system in 1987, and other smaller spills (Integral and GSI 2004).

4.1.2 Secondary Sources

Secondary sources of COIs to the in-water site are groundwater, stormwater, and wastewater discharges from the upland portion of the site. Sediment associated with these discharges or resuspended from one area of the in-water site to another is also a potential secondary source. These secondary sources are also mechanisms of chemical movement to and within the in-water site (discussed further in Section 4.2).

4.1.2.1 Groundwater

Dissolved groundwater plumes at the site are relatively stable and well-documented (Integral and GSI 2004). Figure 4-4 presents a conceptual interpretation of the current approximate configuration of groundwater plumes originating from the upland portion of the site and entering into river sediments. Acute water quality criteria were generally used to define the approximate limits of each of the primary COI plumes at the site in Figure 4-4. Two chemicals, perchlorate and MCB, do not have readily available water quality criteria. For perchlorate a concentration of 20 mg/L was used to define the plume, which is the criterion maximum concentration (CMC) for the protection of aquatic life developed recently by Dean et al. (2004). For MCB a concentration of 1.1 mg/L was used, which is a Tier II, Secondary Acute Value that was developed by Suter and Tsao (1996) for use by the Oak Ridge National Laboratory. Tier II values are surrogate aquatic benchmarks for National Ambient Water Quality Criteria recommended in EPA's (1993b) Proposed Water Quality Guidance for the Great Lakes System.

In the Acid Plant area, residual MCB DNAPL has been observed and a focused investigation has documented the nature and extent of DNAPL in the upland subsurface. DNAPL exists in residual form and is not readily mobile. However, DNAPL likely contributes to the continued presence of dissolved phase MCB in groundwater observed

in upland soils and sediments (Figure 4-4)[16]. DDT is also present in the Acid Plant area. The DDT and MCB groundwater plumes are generally collocated because of the common primary source (i.e., the MPR pond and trench) for these two COIs.

In the Chlorate Plant area, two separate groundwater plumes of hexavalent chromium and perchlorate have been identified (Figure 4-4). Both plumes extend from the former Chlorate Cell Room building to the east toward the river. The plumes overlap but are not identical in their nature or extent. The hexavalent chromium plume is likely related to the use of sodium bichromate as a corrosion inhibitor and to enhance electrical efficiency in the sodium chlorate manufacturing process. The perchlorate plume is likely related to the limited manufacture of sodium perchlorate in the Chlorate Cell Room building during a brief period between about 1958 and 1962.

On the eastern edge of the former Salt Pads, chloride is found in high concentrations in groundwater. This area is immediately downgradient of the former Salt Pads, where salt was historically stockpiled and where salt brine was produced for use in the chlor-alkali manufacturing process that occurred from 1941 to 2001. Even though chloride is a naturally-occurring chemical and is not a primary COI for the site, elevated chloride concentrations are found in groundwater beneath the eastern edge of the salt pads and extending in groundwater beneath sediments in the Salt Dock area. The highest groundwater chloride concentrations are in monitoring well MWA-30 in the upland portion of the site and at CP08D-1 in the in-water portion of the site (Figure 4-4).

4.1.2.2 Stormwater

Stormwater was sampled for the RI during four separate sampling events from 1999 to 2001 (Integral and GSI 2004; USEPA 2005). Stormwater samples were collected in the Acid Plant Area from a storm drain system, prior to mixing with noncontact cooling water. Total DDT and its metabolites were detected at very low concentrations, suggesting that some pesticide-containing material was present in the stormwater that discharges into the Willamette River. However, significant reductions of these constituents in stormwater were observed after the Phase I soil removal interim remedial measure was completed (ERM 2004).

Comprehensive stormwater monitoring was conducted monthly in 2004-2005 as a requirement for the renewal of an NPDES permit for the facility. Stormwater samples were collected between March 2004 through March 2005 (except for months when there was no precipitation) and analyzed for selected legacy and 303(d) constituents. Analyses

[16] DNAPL has been observed on a continuous silt layer in the Acid Plant area of the site.

detected DDT and metabolites at low levels. Further assessment of the detections is being conducted.

4.1.2.3 Wastewater

Wastewater from Arkema was formerly discharged through four outfalls. Noncontact cooling water from the Acid Plant was discharged through Outfall 2. Combustion chamber cooling water from the Acid Plant was pumped to a wastewater treatment system for pH neutralization before discharge through Outfall 4. Cooling water from caustic evaporators was conveyed to Outfall 2. Cooling water from the Chlorine Cell Room was conveyed to Outfalls 3 and 4, and from the chlorine finishing process to Outfall 1. Although these outfalls historically discharged these cooling waters into the Willamette River, only stormwater runoff has been discharged since the plant shut down in 2001.

4.1.2.4 Sediment

DDT and other COIs observed in river sediments adjacent to the property are present primarily because of historical releases from a former process discharge pipe located just north of Dock 1 (near station WB-9) and groundwater discharges to the sediments. Erosion of sediments from one location to another and bank soils may be secondary sources of COIs to other portions of the river.

4.1.3 Source Control

Since 1989, Arkema has conducted several source control measures to improve soil, stormwater, groundwater, and sediment quality at the site. Several groundwater source control measures are ongoing and other source control measures are presently under development. A chronological summary of source control measures that have been completed or that are ongoing at the site is provided below.

Brine Residue Pile and Pond: The brine residue pile and pond were located on Lots 1 and 2. Brine residue, which was comprised of calcium carbonate and magnesium hydroxide, were historically disposed of in either the brine residue pile or pond. The brine residue pile was completely removed from the site in February 1989 and the pond was completely removed in August 1992 (Integral and GSI 2004). The material was transported to Hillsboro Landfill and beneficially used as a soil amendment to the final landfill cap.

Asbestos-containing Residue Removal: In 1992, ATOFINA completed the decommissioning of three surface impoundments. The decommissioning included the excavation of trenches with asbestos-containing residue. The removal action was overseen and approved by DEQ (Integral and GSI 2004).

DDT Removal: In 1994, a trench, on Lot 1 that contained DDT residues was completely excavated, disposed of, and backfilled with clean material. Approximately, 1,700 tons of soil with DDT residues were excavated and disposed of at the Waste Management Subtitle C landfill in Arlington, Oregon.

Phase I and II Soil Removal IRMs: Soil removals were carried out in 2000 and 2001 to address soil containing high concentrations of DDT and chlorobenzene in the Acid Plant area. The Phase I soil removal IRM was performed at the site between September and November 2000. During the Phase I removal, approximately 3,800 tons of soil was excavated from the former MPR pond and trench. These soils were disposed of at the Waste Management Subtitle C landfill in Arlington, Oregon. Additionally, a temporary surface cover was constructed in the unpaved area east of the Acid Plant Area, where unpaved surface soil samples had been collected. The Phase II soil removal IRM was completed in November 2001 in the Acid Plant Area. A total of 915 tons of shallow soil were removed from throughout the Acid Plant Area and disposed of at an Arlington, Oregon landfill.

Soil Vapor Extraction System: A soil VES was installed in December 2000 to extract chlorobenzene mass from subsurface soils. The system was expanded over 2-1/2 years of operation and included five horizontal extraction wells. This system was shut down in 2003.

Stormwater System Improvements: Phase I efforts included the cleanout of stormwater catch basins and subsurface lines, emplacement of filter bags in catch basins, and the removal of some surface soil and placement of temporary cap over a large unpaved area (USEPA 2005). Upon completion of the Phase I and Phase II removal activities, asphalt was placed over the area to direct stormwater directly to surface drains. A temporary impermeable cover was also placed on a fill area on the eastern boundary of the Acid Plant Area to divert storm water runoff directly to surface drains.

Groundwater Cleanup/Source Control: Pilot studies were conducted in the following areas in order to develop remedial strategies for cleanup/source control: *in situ* persulfate injection, DNAPL remediation and hexavalent chromium reduction. Perchlorate bioremediation treatability studies are also ongoing. Based on the success of the DNAPL remediation pilot study, a full-scale air sparging/vapor extraction system was installed and began operating in December 2004. The hexavalent chromium reduction study was also a success and as a result the first phase of calcium polysulfide injections were completed in July 2005. The full-scale persulfate injection chemical oxidation program was also initiated in September 2005. Results from the perchlorate bioremediation study are still pending.

4.2 TRANSPORT PATHWAYS

Three primary potential pathways are of concern:

- Groundwater migration via advection and hydrodynamic dispersion
- Stormwater discharge via outfalls
- Stormwater discharge via overland (sheet) flow from the riverbank soils

These pathways are discussed below.

4.2.1 Groundwater

Groundwater occurs in fill materials and four distinct zones beneath the site (shallow, intermediate, deep, and basalt zones) (Integral 2004a). The general direction of groundwater flow for all zones is towards the river, with discharge to the river. Upward vertical hydraulic gradients were observed in the sediment and groundwater investigations conducted in the river, in the vicinity of Docks 1 and 2 (Integral 2004a).

Even though upland and in-river investigations indicate that upland groundwater discharges to the river, historic discharges from a former process discharge pipe located just north of Dock 1 are the primary source of DDT in sediments. The current dissolved-phase transport of DDT to the river is low relative to these historic deposits. Chlorobenzene and low concentrations of DDT are both present in groundwater, especially in the Acid Plant area. At higher concentrations, chlorobenzene can be a cosolvent for DDT; however, the existing data indicate that even considering cosolvency, the current flux of DDT in groundwater is small compared to the historic deposits. Perchlorate and chromium plumes may also be potential continuing sources via the groundwater to surface water pathway (Integral 2004a).

4.2.2 Stormwater Discharge - Outfalls

Stormwater from Arkema is discharged through four outfalls under NPDES permit No. 100752, none of which have discharged process waste water since the plant closed in 2001. Since issuance of the stormwater NPDES permit in January 2004, all permit limits have been met.

4.2.3 Stormwater Discharge – Overland Flow

With the exception of some erosion of bank soils, little overland transport of chemicals is expected via soil erosion. The northern third of the property consists of open fields of brush and healthy vegetation. The southern two-thirds of the property, where chemical

manufacturing activities took place, is almost entirely covered by pavement, gravel, or a temporary cover system. This area of the property is served by a storm sewer system that conveys stormwater directly to the Willamette River. Overland sheet runoff to the river is not expected.

The river bank in the vicinity of Arkema is partially river beach and steep slopes covered with bank stabilization material that includes large chunks of concrete, asphalt, and other impervious material (Integral 2004a). There is no evidence of large-scale bank erosion, although there was minor sloughing of the bank between Docks 1 and 2 during the 1996 flood (Integral 2004a).

4.3 EXPOSURE PATHWAYS AND POTENTIAL RECEPTOR POPULATIONS

The primary and secondary sources and release mechanisms described above have led to COIs in both abiotic and biotic exposure media at the site (Figures 4-1 and 4-2). Abiotic exposure media are surface water, beach sediments (including seasonally submerged bank soils), and in-water sediments. Biotic exposure media are fish and shellfish that have potentially bioaccumulated COIs via exposure to surface water and sediments.

Human receptors of concern for these exposure media are dockside workers and transient trespassers (Figure 4-1). Dockside workers may be exposed to COIs primarily via incidental ingestion or dermal contact with in-water sediments or beach sediments. Exposure via ingestion of locally caught fish or shellfish is a secondary pathway for dockside worker exposure. Dockside worker exposure via ingestion or dermal absorption of surface water or groundwater is negligible and is not considered for this EE/CA.

Transients at the site may be exposed to COIs primarily via incidental ingestion or dermal contact with in-water sediments or beach sediments. Exposures via ingestion or dermal absorption of surface water or via ingestion of locally caught fish or shellfish are secondary pathways for transient exposure. Transient exposure via groundwater is negligible and is not considered for this EE/CA.

Ecological receptors of concern are in three categories: aquatic biota, semiaquatic mammals, and semiaquatic birds (Figure 4-2). Aquatic biota may be exposed via incidental ingestion or direct contact with surface water, beach sediments, or in-water sediments. Exposure to sediments also includes groundwater, which may be an important component of sediment porewater. Aquatic biota can also be exposed indirectly via consumption of food. However, this secondary pathway will not be quantitatively evaluated in the EE/CA as discussed in Section 3.5.3.

Semi-aquatic birds and mammals may be exposed to COIs in abiotic media via ingestion of beach sediments, in-water sediments, and prey. Although ingestion of surface water is possible for these receptors, it is considered a negligible pathway and is not evaluated in the EE/CA.

5.0 DATA GAPS AND DATA QUALITY OBJECTIVES

This section presents the approach in evaluating data gaps to meet the removal action objectives (RAOs) for the Arkema in-water site. The data gap evaluation process begins with a statement of the RAOs as presented in the AOC followed by a section introducing removal action alternatives and technologies, including sampling and analysis "tools", which will be considered in the EE/CA. Specific data gaps are then evaluated based on a review of existing data (Section 3.1) and locations of site concentrations that exceed SQVs (Section 3.6) that may pose a principal threat to the environment and human health.

The following data gap evaluation focuses on the COIs in sediments which will be used to define the boundary of the principal threat area. Groundwater and porewater evaluations will be conducted as necessary to address onsite source control and potential recontamination. In general, the following data gaps have been identified for the site:

- Sediment Chemical Quality Characteristics – additional evaluation is required for areas offshore of the salt pads and in the vicinity of the Salt Dock, between the Salt Dock and Dock 1 and immediately offshore of these docks, and downstream of Dock 2;
- Sediment Physical and Engineering Characteristics – additional evaluation is required for the in-water portion of the site located within the preliminary RAA boundary; and
- Water Quality/Chemical Mobility Testing – evaluation of in-water areas that could be dredged such as between Dock 1 and Dock 2.

5.1 EVALUATION PROCESS

5.1.1 Removal Action Objectives

The following RAOs for the Arkema in-water RA are noted in the AOC dated June 27, 2005:

1. Reduce human health risks to acceptable levels from direct contact with and incidental ingestion of chemicals of concern (COCs) in sediments and riverbank within the RAA.
2. Reduce COC concentrations in sediments and riverbank within the RAA to levels that will result in acceptable risks to humans that eat fish and shellfish from the Willamette River.

3. Reduce human health risks to acceptable levels from direct contact with and incidental ingestion of water with COCs within the RAA.
4. Reduce ecological risks from contact with and ingestion of COCs in sediments or riverbank material or prey within the RAA to acceptable levels.
5. Reduce ecological risks to acceptable levels from contact with and ingestion of water with COCs within the RAA.
6. Eliminate the potential for migration of contaminants at unacceptable levels from the RAA to the Willamette River.
7. Reduce contaminant flux from uplands, riverbank, and sediments so that recontamination of any sediment or riverbank caps put in place does not occur.

In accordance with EE/CA guidance, the removal action objectives are intended to address the principal threat area of the site.

5.1.2 Removal Action Technologies and Alternatives

Removal action technologies and alternatives will be evaluated to address the RAOs listed in Section 5.1.1. Only the most suitable technologies that apply to the medium or source of contamination will be considered for the development, comparative evaluation, and selection of RA alternatives (USEPA 1993a). A brief description of each qualified technology is presented below, followed by an evaluation of sampling and analysis methods required to determine the potential application of each alternative for the in-water site (USEPA 1998; USACE 1998, 2003).

- **Monitored Natural Recovery**. This technology depends on natural processes (e.g., natural sediment accumulation, mixing, chemical degradation and diffusion, benthic community succession) to achieve RAOs. Long-term monitoring to confirm recovery is an important component of this alternative.
- ***In Situ* Capping** – This technology involves the placement of a covering or cap over an *in situ* deposit of contaminated sediment. The cap may be constructed of clean sediments, sand, or gravel, or may involve a more complex design with geotextiles, liners, carbon-activated material (amended cap), or other materials in multiple layers. Capping may be used to enhance natural recovery of the sediments or to isolate the contaminated sediments.
    - **Thin-layer Enhancement –** Thin-layer caps can be constructed by slowly and gently distributing a thin layer (e.g., 6 to 12 in) of clean, sandy material on top of existing problem sediments. The design must account for potential bioturbation of the cap by aquatic organisms, sedimentation, and erosional processes.

  - **Isolation** – Isolation caps are typically constructed by placing at least one layer of clean sediment of required thickness over existing problem sediments. As a viable alternative, the design must account for potential bioturbation of the cap by aquatic organisms; consolidation of the capping material and underlying sediment; erosion due to river currents, waves, tides, storms, and vessel propeller scour; operational concerns including placement inaccuracies; and contaminant isolation. The effect of cap placement on slope stability also needs to be evaluated with an isolation cap.

- **Dredging/Removal** – Both mechanical (land-based or barge-mounted) and hydraulic dredging technologies will be evaluated for dredging portions of the RA. Mechanical dredges apply mechanical forces to dislodge the sediment at or near in-place densities. The most common mechanical dredge consists of a crane, derrick or excavator, mounted on a floating barge that removes sediment with a clam-shell bucket or similar device (e.g., cable arm environmental bucket). By contrast, the hydraulic cutterhead dredge cuts into the river bed, pumps the sediment through a pipe, and discharges it as a solids and slurry mixture directly to a disposal site. If dredging becomes a preferred alternative, the equipment selected may be determined by considerations such as dredge volume requirements, entrainment of water, sediment resuspension, water quality impacts, equipment availability, and disposal options.
- **Disposal** – If sediments are dredged, disposal options considered may include an appropriate landfill, a nearshore confined disposal facility (CDF) (constructed along the Willamette River shoreline), and an in-water confined aquatic disposal (CAD) facility. A CDF is typically constructed adjacent to an upland area such that the site can be used as an extension of the upland when the site is filled with sediment. A CAD typically involves placement of dredged material in a submerged, aquatic site followed by capping with clean material.
  - Subtitle C or D Landfill – Upland disposal options may include landfills in Arlington, Oregon and Roosevelt, Washington or other similar landfill options.
  - Nearshore CDF – Construction of a nearshore CDF may be an option for the Arkema in-water site. Also, the proposed Port of Portland Terminal 4 CDF site may be operational and available when implementation of the RA begins at the Arkema in-water site. Other CDF sites along the Willamette could also be available at the time of the Arkema RA (e.g., Swan Island).
  - In-Water CAD – No CAD sites have been identified on the Willamette or Columbia Rivers at this time.

- **Treatment** – The feasibility and cost-effectiveness of sediment treatment depends on a number of factors including the quantity of material to be treated, contaminant types and concentrations, the target post-treatment contaminant concentrations, and the potential end uses and marketability of the treated material. While these factors will be considered in the assessment of treatment technologies as part of the EE/CA, recent experience at other sediment sites in the U.S. suggests that treatment at the Arkema site may be relatively less feasible than competing disposal options.

Depending on the results of the upland remedial measures, hydraulic containment may be required to assure that source control measures are effectively reducing any principal threats and/or the potential for cap recontamination before implementation of the in-water RA. Construction of a sheet pile wall along the shoreline or in-water or other hydraulic or *in situ* source control measures may be evaluated in the EE/CA.

The selected remedy(s) must achieve the RAOs presented in Section 5.1.1. Table 5-1 presents the sampling and analysis tools that will be considered for each potential remedial action technology for the site. Table 5-2 presents the sampling and analysis tools that may be considered for each potential disposal alternative but initiated by the owner of each site (e.g., Port of Portland's Terminal 4 CDF). These tools are discussed in more detail in the following sections and the accompanying FSP and QAPP. Details on specific data quality objectives (DQOs) for the EE/CA are also presented in the accompanying QAPP.

Table 5-1. Sampling/Analysis Tools – Potential Remedial Action Technologies.

Sampling/Analysis Tools		Monitored Natural Recovery	Thin-Layer Enhancement Cap	Isolation or Amended Cap	Sediment Dredging/Disposal – Characterization
Sediment Surface Grab Samples					
Chemical Analyses (COIs, Conventionals[a])		X	X	X	X
Physical Analyses (grain size)		X	X	X	X
Bioassays		X	X	X	X
Sediment Borings (In-Water and Bank)					
Chemical Analyses (COIs, TOC)		-	-	X	X
Geotechnical Analyses					
	Grain Size	-	-	X	X
	Standard Penetration Test	-	-	X	X
	Atterberg Limits	-	-	X	X
	Specific Gravity	-	-	X	X
	Moisture/Bulk Density	-	-	X	X
	Consolidation	-	-	X	
	Shear Strength[b]	-	-	X	X
Water Quality					
	DRET[c]	-	-	-	X
	EET[c]	-	-	-	X
	SBLT[c]	-	-	-	X
	TCLP[c]	-	-	-	X
	Oregon ATT[d]	-	-	-	X
	Column Settling	-	-	X (cap material)	X
Surface Water Sampling (Water Quality Testing Related to Dredging and Disposal)					
Chemical Analyses		-	-	-	X
Conventional Analyses (TOC, Anions/Cations)		-	-	-	X
Groundwater Sampling					
Seepage Velocity		✓	✓	✓	-
Chemical Analyses		✓	✓	✓	-
Conventional Analyses (TOC, Anions/Cations)		✓	✓	✓	-
Stormwater Sampling (Recontamination)					
Flow Rates		X	X	X	X
Chemical Analyses (COIs)		X	X	X	X
Bathymetry/Topography		✓	✓	✓	✓
Sedimentation Rates[e]		✓	✓	✓	-

Table 5-1. Sampling/Analysis Tools – Potential Remedial Action Technologies.

Sampling/Analysis Tools	Monitored Natural Recovery	Thin-Layer Enhancement Cap	Isolation or Amended Cap	Sediment Dredging/Disposal – Characterization
Erosion/Stability Analysis				
Willamette River	X	X	X	X
Prop Wash	X	X	X	X
Bank/slope	-	-	X	X
Seismic	-	-	X	X

Notes:

✓ Adequate data available for this sampling/analysis tool.

X Additional data required for this sampling/analysis tool.

- Data not required for the EE/CA.

[a] Conventionals for bioassays include total solids, total sulfides, ammonia and TOC.

[b] May include *in situ* vane shear, cone penetrometer testing, and/or laboratory shear strength testing.

[c] Suite of conventional and chemical analyses including anions/cations, TOC, COIs

[d] The Aquatic Toxicity Test (ATT) is required by Oregon for all pesticide wastes in determining its acceptability into a Subtitle D Landfill.

[e] Tools for evaluating sedimentation analyses include radioisotope dating, sedimentation stakes, sediment traps, comparison of bathymetry surveys, and hydrodynamic modeling.

Table 5-2. Sampling/Analysis Methods – Potential Disposal Alternatives

Sampling/Analysis Tools		Onsite Disposal	Offsite Disposal	
		Nearshore CDF	Nearshore CDF (Terminal 4)	Subtitle C/D Landfill
Sediment/Soil Borings				
Chemical Analyses (COIs, TOC)		X	[a]	-
Index Parameters				
	Grain Size	X	[a]	-
	SPT	X	[a]	-
	Atterberg Limits	X	[a]	-
	Specific Gravity	X	[a]	-
	Moisture/Bulk Density	X	[a]	-
Geotechnical				
	Consolidation	X	[a]	-
	Shear Strength[b]	X	[a]	-
	Permeability	X	[a]	-
Groundwater Sampling				
Seepage Velocity		✓	[a]	-
Chemical Analyses (COIs)		✓	[a]	-
Conventional Analyses (TOC, Anions/Cations)		✓	[a]	-
Bathymetry/Topography		✓	[a]	-
Sedimentation Rates[c]		✓	[a]	-
Erosion/Stability Analysis				
Willamette River		X	[a]	-
Prop Wash		X	[a]	-
Bank/slope		X	[a]	-
Seismic		X	[a]	-

Notes:

✓ Adequate data available for this sampling/analysis tool.

X Additional data required for this sampling/analysis tool.

\- Data not required for the EE/CA.

[a] Arkema assumes sampling and analysis requirements will be available for the Terminal 4 or other offsite nearshore CDF.

[b] Includes *in situ* vane shear, cone penetrometer testing, and/or laboratory shear strength testing.

[c] Tools for evaluating sedimentation analyses include radioisotope dating, sedimentation stakes, sediment traps, comparison of bathymetry surveys, and hydrodynamic modeling

5.2 HISTORY, CULTURAL RESOURCES, AND LAND USE

There are no data gaps that have been identified with respect to historical site operations. The Arkema site operational history is sufficiently understood to allow an evaluation for purposes of the EE/CA of how operations have influenced the nature and extent of contamination within the current RAA boundary. No additional data collection regarding the history of the Arkema site is proposed, but if additional data become available, the data will be incorporated into the overall data set.

Existing cultural resources information, subject to acceptance by the Tribes, is sufficient to perform the work specified for the EE/CA. Based on recent studies, no cultural resources have been identified at the site; however, sediment from any additional surface samples or borings may be examined during sample collection for artifacts or other deposits of archaeological significance, if new information suggests such examination is necessary.

No data gaps exist in the understanding of current land uses. Currently, the site is inactive, except for ongoing upland remediation operations. Future land uses at the Arkema site will remain heavy industrial. River-based access could remain a component of any future use.

5.3 HYDRODYNAMIC CHARACTERISTICS OF THE RIVER

Recent studies for the Portland Harbor RI/FS have evaluated bathymetry, erosion and deposition rates, and other hydrodynamic conditions within all or portions of the Arkema in-water site (see Section 3.2).

Bathymetric surveys that cover most of the Arkema in-water site were performed for the Portland Harbor RI in 1999, 2002, 2003 and 2004. These surveys were used to generate bathymetric surface base maps of the Willamette River (LWG 2004). The current information for the site is adequate to evaluate remediation alternatives (i.e., capping, dredging, hydraulic containment) as part of the EE/CA. A more detailed bathymetric survey of the in-water portions of the site and a topographic survey of the banks may be required in support of the remedial design.

Sedimentation rates have been determined by various methods in the vicinity of the site including bathymetry difference maps, hydrodynamic modeling, and sediment stakes (refer to Section 3.2). These data and the requirement for periodic dredging indicate that over long time frames there is net deposition of sediments to most areas of the Arkema in-water site. Because of the short-term fluctuations in accretion versus deposition at the site and the short duration of the Portland Harbor sedimentation studies, there is some uncertainty in the actual long-term sedimentation rate for the site. However, the

sediment stake data, which were collected downstream of Dock 2, indicate a predicted sedimentation rate of 3 to 5 cm per year. The current information is adequate to support the EE/CA.

5.4 SEDIMENT QUALITY CHARACTERISTICS

The AOC establishes a preliminary RAA but requires delineation of a final boundary for the principal threat area in the final EE/CA.

A "multiple lines of evidence" approach will be used to define the final RAA sediment boundary. The "multiple lines of evidence approach" includes comparisons to sediment screening values (as described in Section 3.6) and sediment toxicity[17]. Comparisons will be made to existing data compiled from historical sediment studies at the site and to additional data collected as identified in the data gap analysis. Extensive sediment sampling has been completed over portions of the site, especially between Docks 1 and 2 (Figure 3-1 to Figure 3-3). However, additional sediment quality data are required for the following areas (beginning upstream of the Arkema site) to complete the EE/CA:

- Surface (0 to 1 ft)[18] sediment chemistry and possibly bioassay[19] data to address ecological risk in nearshore sediments associated with groundwater transport of sodium chloride. The areas offshore of the salt pads and in the vicinity of the Salt Dock require additional evaluation.
- Surface sediment chemistry and possibly bioassay data to address ecological and human health risk in nearshore sediments associated with groundwater transport of chromium. The area requiring additional evaluation includes the area between the Salt Dock and Dock 1 and immediately offshore of these docks.
- Surface sediment chemistry and possible bioassay data to address ecological and human health risk in nearshore sediments associated with groundwater transport of perchlorate. Additional sampling and testing is required between the Salt Dock and Dock 1.
- Surface sediment chemistry and possible bioassay data to address ecological and human health risk in nearshore sediments associated with sediment DDTr and

[17] The multiple lines approach focuses on COIs in sediments to define the boundary of the principal threat area.

[18] Surface sediments are defined for the Portland Harbor Superfund project as 0-1 ft. For consistency, Arkema has defined surface sediments at the same depth.

[19] Sediment bioassays may be tested concurrently with chemical analyses or required based on chemicals above SQVs (tiered approach).

MCB concentrations. Additional sampling and testing is required offshore of Docks 1 and 2 and downstream of Dock 2.

- Subsurface sediment borings to further delineate the extent of total chromium and perchlorate in sediments between the Salt Dock and Dock 1, specifically near station C366 (see Figure 3-2).
- Subsurface sediment borings to further delineate the extent of DDTr and MCB contamination in sediments for the following areas:
  - Dock 1 – Upstream in the vicinity of stations C359 and WB-23 and along the dock face near station C356. The additional borings will be used to delineate the upstream RAA boundary for DDTr and MCB in sediments (Figure 3-2).
  - Between Docks 1 and 2 – The area closer to Dock 2 to further delineate the depth of DDT near stations WB-13 and WB-14 (Figure 3-2).
  - Downstream of Dock 2 in the vicinity of station C348 – The additional borings will be used to delineate the downstream RAA boundary for DDTr and MCB in sediments (Figures 3-2 and 3-3).

5.5 SEDIMENT PHYSICAL AND ENGINEERING CHARACTERISTICS

A suite of physical tests is proposed to evaluate sediment properties pertinent to dredging and capping technologies, dredged material transport and placement, dredged material behavior in a disposal site, potential short-term impacts at the dredge and disposal sites, capacity of existing sediments to provide foundation support for capping material, and the viability of sheet pile wall construction for nearshore containment (refer to Table 5-1). The following tests will be required to evaluate these technologies.

5.5.1 Index Parameters

5.5.1.1 Grain Size

Grain size provides information on site geologic character and engineering properties of sediment proposed for capping or dredging. Sediment grain size information is available for most surface sediments previously collected from the site. However, there is limited quantitative grain size data available for the subsurface sediments within the preliminary RAA boundary.

5.5.1.2 Atterberg Limits

Atterberg limits, which include the liquid limit, plastic limit, and the plasticity index, are used to define plasticity characteristics of cohesive sediments and are a useful index parameter for sediment strength correlations. There are only limited Atterberg limit data available from historical studies within the current RAA boundary. Selected fine-grained surface and subsurface sediments collected for grain size will also be analyzed for Atterberg limits.

5.5.1.3 Specific Gravity

The specific gravity of sediment samples is used to determine the dispersal and settling characteristics of the sediment during dredging and disposal. Limited data are available for specific gravity in sediments between the docks and nearshore (Portland Harbor RI sampling locations only). There are also limited data available for upland soils.

5.5.1.4 Moisture/Bulk Density

Moisture content is used to determine the initial *in situ* void ratio of the sediment and to estimate the short-term bulking (or increase in volume) during dredging activities, and for correlation with other geotechnical parameters. There have been no direct measurements in site sediments for moisture content or bulk density. Selected samples will be analyzed in support of the remedial alternative selection.

5.5.2 Evaluation of Cap Integrity

Cap design involves the evaluation of long-term stability and integrity based upon physical and chemical parameters expected at the site. Parameters to evaluate in the design of a cap include chemical isolation, cap thickness, cap materials, cap armoring, strength of underlying sediments, bioturbation, cap erosion and scour, vessel prop wash, slope stability, and settlement/consolidation (USACE 1998, USEPA 1998). A description of the tests to support a cap design is presented below. None of these tests has been conducted previously on in-water site sediments. Representative sediment from areas that could be capped will be collected for this testing (refer to Section 6).

5.5.2.1 Shear Testing

In situ and laboratory shear tests are used to determine bearing capacity and slope stability design parameters for cap placement (Holtz and Kovacs 1981). *In situ* shear testing can be evaluated either by vane shear or cone penetrometer. Both *in situ* tests can be performed from a barge during drilling operations (i.e., co-located with sediment quality testing). The cone penetrometer is preferred over the vane shear in cohesionless sediments, most likely found at the Arkema site. The laboratory shear testing is used to

evaluate foundation capacity of a cap and for dredge equipment selection and production rates. Short-term critical loading may occur immediately following cap placement, and also can occur as a result of seismic activities. The appropriate shear test to model short-term critical loads is the unconsolidated, undrained (UU) triaxial shear test. Long-term critical loading is best modeled by the consolidated, undrained (CU) triaxial test with pore pressure measurements.

5.5.2.2 Consolidation Testing

Consolidation tests are performed to determine the potential consolidation of sediment deposits under loading conditions associated with capping materials. An understanding of the consolidation of underlying sediment is important in evaluating the effective (or minimum) thickness of a cap (USACE 1998). The effective thickness of a cap is reduced by the consolidation in the underlying sediment. Standard vertical loads are reduced to include the equivalent varied thickness of a cap (modified EM-1110-2-5027 for lower loads).

5.5.3 Water Quality/Chemical Mobility Testing During Dredging and Disposal

None of these tests has been conducted previously on in-water site sediments. Representative sediment from areas that could be dredged will be collected for this testing (refer to Section 6).

5.5.3.1 Elutriate Testing

Elutriate testing is required on representative dredged material to provide an assessment of contaminant mobility during dredging and disposal operations. The dredging elutriate test (DRET) and effluent elutriate test (EET) are used to predict the potential short-term contaminant release. The DRET method is commonly used for examining potential short-term impacts at the point of dredging or capping. The EET is used to predict the quality of effluent from the filling of an upland or nearshore CDF or dewatering facility using hydraulic dredging. The tests are generally conducted in accordance with USACE Engineering Research and Development Center (ERDC)-recommended procedures (USACE 2003; USEPA/USACE 1998; DiGiano, et al. 1995; Palermo 1986).

5.5.3.2 Column Settling Test

The column settling test is used to model the settling behavior of sediments (USACE 1993). The objective of the test is to predict the gravity settling rate and behavior of dredged material upon placement into a nearshore CDF disposal site. Results of the

testing are used to select an appropriate placement method, predict potential water quality effects in or near the disposal area, and design the disposal site area.

5.5.4 Potential Leaching to Groundwater (Nearshore CDF, Landfill or CAD Site)

The sequential batch leaching test (SBLT) is used to evaluate possible leachate quality from dredged materials placed in a nearshore or upland CDF. It is recommended that upland groundwater be used to run the SBLT, preferably groundwater located upgradient of the proposed disposal site. Alternatively, distilled water can be used. The design recommendations for the SBLT apparatus are described by Myers et al. (1992) and Brannon et al. (1994).

The toxicity characteristics leaching procedures (TCLP) test is used to evaluate possible leachate quality when dredged sediments are disposed of into a landfill. Other evaluation criteria may include hazardous waste determination, data on the generation and loss of free liquid, and other landfill-specific acceptance criteria.

Oregon requires the Aquatic Toxicity Test (ATT) for wastes containing pesticide active ingredients listed in 40 CFR 261.33(e) and (f). A representative sample must exhibit a 96-hour aquatic toxicity LC50 equal to or less than 250 mg/L to be acceptable in a state Subtitle D Landfill (OAR 340-109-0001).

5.6 HYDROGEOLOGIC CHARACTERISTICS

Groundwater characteristics have been evaluated for site upland soils and in-water sediments including the transition zone between sediments and overlying water (Integral 2004a, 2005b). Upland groundwater zones and their characteristics (including hydraulic gradient and conductivity measurements) are summarized in Section 3.2.2.2. Transition zone groundwater seepage rates were measured as part of the recent Portland Harbor RI groundwater study as described in Section 3.2.2.1. The information from these studies will be used in calculations and modeling to estimate long-term contaminant release or loss associated with placement of an isolation cap. An understanding of groundwater advection in the sediments is important in evaluating the effective (or minimum) thickness of a cap. This information will also be beneficial in evaluating hydraulic containment alternatives for the site, if necessary. No additional hydrogeologic data are required in support of the EE/CA.

5.7 RECONTAMINATION SOURCE CHARACTERIZATION

The Portland Harbor groundwater site work and monitoring during the Stage 1 and 2 investigations provide a good baseline for groundwater impacts from the Arkema site (Integral 2003, 2005b). Upland source control actions are being conducted and scheduled for completion by October 2007, before implementation of the in-water removal action. Groundwater monitoring will continue to verify the effectiveness of the planned upland treatments. No additional data are required in support of the EE/CA. However, in addition to the upland monitoring, an in-water monitoring program may be performed to verify the effectiveness of the source control actions for COIs that sorb onto sediments (i.e., DDTr, trivalent chromium). Monitoring tools that will be considered include the Trident Probe and UltraSeep®, which have been shown to be effective in measuring transition zone water (Integral 2005b). The details of the monitoring, if needed, will be presented in the final EE/CA.

6.0 RA CHARACTERIZATION ACTIVITIES

This section provides the rationale for additional RA characterization activities proposed for the Arkema in-water site before completion of the EE/CA.

6.1 SEDIMENT QUALITY CHARACTERISTICS

This section presents the sampling design and rationale for supplementary evaluation of the sediment quality characteristics at the Arkema in-water site. Additional information on sediment quality characteristics is required to evaluate the nature and extent of contamination within the preliminary RAA boundary and to support the ecological and human health risk screening. These additional data will be used to delineate the final RAA boundary in the EE/CA.

6.1.1 Nature and Extent of Contamination

6.1.1.1 Rationale

The primary goal of sediment sampling is to define the vertical and lateral extent of COIs, and to define the final RAA boundary and associated removal action subareas[20]. The sampling pattern will focus on refining sediment COIs boundaries that could be considered principal threats in areas identified in previous investigations (e.g., Arkema's Stage 1 and 2 studies and Portland Harbor RI studies). As described in Section 5.4, additional sediment borings are required upstream of and near Dock 1, and upstream and downstream of Dock 2.

6.1.1.2 Sampling Strategy

A total of 27 borings will be drilled to a depth of up to 20 feet below mudline (or refusal) to evaluate the extent of contamination (i.e., DDT and MCB, chromium, and perchlorate) within the preliminary RAA boundary. The borings will be positioned in the following locations (see Figures 6-1 to 6-3):

[20] The RAA boundary may be subdivided into multiple subareas, based on variation of COIs and applicable remedial technologies.

Chromium and Perchlorate

- A cluster of four borings to confirm the extent of total chromium and perchlorate in sediments near station C366. The borings will be within 50-75 ft of this station. (proposed boring locations WB-26 to WB-29).

DDTr and MCB

- A transect of two borings beginning approximately 50 ft offshore of the high water line, and located 75-100 ft upstream of stations C359 and WB-23 (upstream of Dock 1). Additional borings will assist in understanding the extent of DDTr, MCB, total chromium, and perchlorate in sediments upstream of these locations. (WB-30 to WB-31)
- A single boring shoreward of WB-23 and downstream towards Dock 1. Sediment borings have not been collected in this area of the site to determine the vertical extent of DDTr and MCB in sediments near the bank. Samples collected from this boring will also be analyzed for total chromium and perchlorate. (WB-32)
- A single boring offshore of C359. Station C359 showed DDTr concentrations above the PEC to a depth of 12 ft below mudline. An additional boring offshore of this location will assist in understanding the lateral extent of problem sediment in this area of the site. Samples collected from this boring will be analyzed for DDTr, MCB, total chromium, and perchlorate. (WB-33)
- A cluster of three borings within 50 to 75 ft of station C356 located at the face of Dock 1. Station C356 showed DDTr concentrations above the PEC to a depth of approximately 8.5 ft below mudline. The cluster of proposed borings will assist in delineating the extent of DDTr and MCB in sediments in the vicinity of station C356. Samples collected from these borings will also be analyzed for total chromium and perchlorate. (WB-34 to WB-36)
- A transect of three borings beginning within approximately 100 ft of the high water line and positioned between station WB-13 and WB-14 and the upstream edge of Dock 2. Sediment borings have not been collected in this area of the site to determine the extent of DDTr and MCB in sediments. Information obtained from these borings will assist in evaluating the downstream boundary of the principal threat area. (WB-37 to WB-39)
- A line of two borings between the face of Docks 1 and 2, one located approximately 75 ft offshore of WB-14, the other located approximately 75 ft downstream of WB-7. Information obtained from these borings will assist in evaluating the channel side boundary of DDTr and MCB in the principal threat area. (WB-40 to WB-41)

- Three transects of three borings downstream of Dock 2 evenly spaced between the downstream edge of Dock 2 and station C348. One boring is positioned offshore of station WB-19. Sediment borings have not been collected in this area of the site to determine the extent of DDTr and MCB in sediments. Information obtained from these borings will assist in evaluating the downstream boundary of the principal threat area. (WB-42 to WB-50)
- A transect of two borings located approximately 75-100 ft downstream of station C348. Station C348 showed DDTr concentration above the PEC to a depth of approximately 8 feet below mudline. Additional borings downstream of this location will assist in evaluating the downstream boundary of the principal threat area. (WB-51 to WB-52)

Several of these borings will be co-located with borings proposed for geotechnical, physical, and water quality testing (i.e., CST, EET, DRET, SBLT, TCLP, ATT) described below. More than one boring will be required at several of these locations for the collection of undisturbed samples and to provide enough sediment for the proposed tests.

A hollow-stem auger (or equivalent) advanced with a drill rig positioned on a barge will be used to complete the borings. Samples will be collected continuously at 2 ft intervals using a Gregory Undisturbed Sampler (GUS) or Osterberg Sampler and stainless steel Shelby tube. A large-volume split-spoon sampler may also be used for sampling (refer to FSP).

6.1.1.3 Analytical Strategy

Sediment samples will be collected continuously in each boring at 2-ft intervals and selected samples may be analyzed based on field observations (e.g., visual, field screen with PID) for the following:

<u>Stations WB-26 to WB-36 only</u>

- Total chromium by EPA Method SW846-6010B
- Perchlorate by EPA Method 314.0 (modified for sediments)

<u>All Proposed Borings</u>

- Chlorinated pesticides by EPA Method SW846-8081A
- Volatile organic compounds by EPA Method SW846-8260B
- Total organic carbon by EPA Method SW846-9060A (modified for sediments)

Up to three samples will be selected initially for analysis from each boring for a total of 77 samples plus QC (e.g., field duplicates). All other samples will be archived. Table 6-1 presents the proposed sampling and testing of the sediment borings. The actual sample(s) selected for analysis from each boring will be dependent on field observations.

6.1.2 Ecological and Human Health Risks

6.1.2.1 Rationale

In addition to defining the spatial extent of sediment COIs within the site boundary, surface sediment samples will be used to evaluate the potential risks to human health and the environment, including benthic community and wildlife receptors. A tiered approach of sediment chemistry and bioassay testing is proposed. The locations of planned surface samples are provided below, followed by the analytical strategy and proposed approach for interpreting the data in support of the EE/CA.

6.1.2.2 Sampling Strategy

Twenty-nine surface sediment (0-1 ft) samples are proposed for collection in support of the EE/CA[21]. The sampling pattern will focus on bounding areas of elevated COIs in sediments identified in previous investigations (e.g., Portland Harbor Round 2 study) that could be considered within or near the principal threat areas. Many of the stations will be co-located with sediment borings proposed in Section 6.1.1. As described in Section 5.4, additional surface sediment samples are required in four areas onsite (plus reference locations) including (Figures 6-1 to 6-3):

- Salt Dock and upstream of this area (WS-56 to WS-61)
- Between Dock 1 and the Salt Dock (WS-23, WS-27, WS-29 to WS-36, WS-55)
- Offshore of Docks 1 and 2 (WS-37, WS-40 to WS-42, WS-45, WS-48)
- Downstream of Dock 2 (WS-46, WS-47, WS-49 to WS-52)
- Reference sediments from EPA-approved ambient upstream locations on the Willamette River[22] (number and location to be determined based on physical characteristics of site sediments)

[21] The total number does not include reference samples collected from an upstream (upgradient) location to be determined.

[22] EPA-approved reference stations LW2-U1C through LW2-U6C are between RM 15 and RM 26 on the Willamette River.

6.1.2.3 Analytical Strategy

Surface samples will be analyzed for the following chemicals:

Upstream of Salt Dock (WS-56 to WS-61)

- Conventionals (TOC, total sulfides, ammonia)[23]
- Chloride by EPA Method 300.0
- Total chromium by EPA Method SW846-6010B
- Perchlorate by EPA Method 314.0 (modified for sediments)
- Chlorinated pesticides by EPA Method SW846-8081A

Dock 1 to Salt Dock (WS-23, WS-27, WS-29 to WS-36, WS-55)

- Conventionals (TOC, total sulfides, ammonia)
- Chloride by EPA Method 300.0
- Total chromium by EPA Method SW846-6010B
- Perchlorate by EPA Method 314.0 (modified for sediments
- Chlorinated pesticides by EPA Method SW846-8081A

Offshore of Docks 1 and 2 (WS-37, WS-40 to WS-42, WS-45, WS-48)

- Conventionals (TOC, total sulfides, ammonia)
- Perchlorate by EPA Method 314.0 (modified for sediments)
- Chlorinated pesticides by EPA Method SW846-8081A
- VOCs by EPA Method SW846-8260B

Downstream of Dock 2 (WS-46, WS-47, WS-49 to WS-50)

- Conventionals (TOC, total sulfides, ammonia)
- Chlorinated pesticides by EPA Method SW846-8081A
- VOCs by EPA Method SW846-8260B

[23] TOC by EPA Method SW846-9060A modified for sediments, Total Sulfides by EPA Method SW846-9034, and Ammonia by Plumb 1981.

Reference Locations (to be determined based on physical characteristics of site sediments)

- Conventionals (TOC, total sulfides, ammonia)
- Chloride by EPA Method 300.0
- Total chromium by EPA Method SW846-6010B
- Perchlorate by EPA Method 314.0 (modified for sediments)
- Chlorinated pesticides by EPA Method SW846-8081A
- VOCs by EPA Method SW846-8260B

COI results exceeding corresponding PEC values will be tested for the following EPA-recommended bioassays (tiered approach):

- 10-day growth and survival in the midge *Chironomus tentans*– USEPA (2000b) Test Method 100.2.
- 28-day growth and survival in the amphipod *Hyalella azteca* – USEPA (2000b) Test Method 100.4

Toxicity testing will follow procedures recommended for the harbor-wide investigation of risks to benthic organisms (Windward et al. 2005) and described in the accompanying QAPP. These solid-phase growth and survival tests were selected as measurement endpoints to help predict the potential for benthic community effects and to define principal threats associated with COIs for the site. However, some of the COIs are total dissolved solids or salts of common compounds that are mildly toxic, highly soluble, have a low affinity for the solid phase sediment matrix, and are not routinely managed pursuant to CERCLA. Consequently, additional sediment toxicity testing is proposed to segregate the effects of these substances and identify their relative importance as principal threats at the site.

Selected sediment samples collected upstream of Dock 1 and in the vicinity of the Salt Dock will be evaluated for possible biological effects concurrently with chemical testing (Table 6-2). Sodium and potassium salts of perchlorate and chloride have been shown to be associated with groundwater discharging into river sediments from upland sources (Integral 2003). These chemicals may cause sediment toxicity as a component (pore water) of the bulk sediment sample but are not expected to adsorb onto sediments as they pass through the sediments into the overlying water. Therefore, toxicity test methods conducted on selected sediment samples in the vicinity of the Salt Dock will be modified in order to reduce the effects of these chemicals found in the porewater. Overlying water in the test containers will be replaced or "purged" twice daily to reduce their concentration levels before introducing the organisms. The purging technique will be adapted from that recommended by Barton (2002) for reducing ammonia levels in

sediment porewater. The process will continue until total dissolved solids (TDS) concentration, conductivity, or pH in the porewater is reduced to ambient or tolerant levels[24], as defined in the QAPP. Selected samples will also be tested without purging for confirmation purposes and to assist in interpreting the chemical and toxicity testing results (see Co-Occurrence Analysis below). Testing methodology is discussed further in the QAPP.

Table 6-2 presents the proposed sampling and testing of the surface sediment samples.

6.1.2.4 Multiple-Lines-of-Evidence Approach

Chemistry and toxicity testing results will be evaluated using multiple lines of evidence in a tiered approach to assist in delineating the final RAA boundary (Table 6-3). The lines of evidence will be evaluated in the following sequence:

- Statistical significance of the test results – Do individual locations exceed *de minimis* levels of concern?
- Biological effects thresholds – Do individual stations and endpoints exceed biological effects thresholds for potential minor or significant effects.
- Geo-spatial characterization – Are there areas of contiguous stations that exceed biological effects thresholds?
- Co-occurrence and relative concentration of chemicals of concern in sediments – Are observed levels of toxicity explained by the presence and concentrations of chemicals of concern in sediments for the site?

Statistical Significance

Toxicity in site sediments will be compared statistically to that in reference sediments. The harbor-wide sediment toxicity testing program (Windward et al. 2005) has adopted statistical comparisons to negative control sediments to increase test sensitivity and reliability of empirically derived sediment quality values. However, site-specific testing typically relies on comparisons to reference conditions in order to isolate chemical toxicity from other environmental stressors associated with benthic habitat conditions such as sediment grain size and organic carbon content. Consequently, for the determination of an area of principal threats, the upstream reference stations established for the harbor-wide program (Windward et al. 2005) will be used to identify reference locations for comparisons to site sediments.

[24] As much as 5-10 days of purging may be required before test initiation.

Following appropriate transformations[25], data will be evaluated for normality and for homogeneity of variances to determine whether parametric or nonparametric statistics will be used. Data that satisfy assumptions or normality and homogeneity of variances will be evaluated using a one-tailed[26] parametric Student's t-test with alpha of 0.05. Data that do not satisfy assumptions of normality and homogeneity will be evaluated using a one-tailed nonparametric procedure such as the Mann-Whitney U-test.

Site stations that are not significantly different from the reference stations will be judged unaffected (i.e., are below any *de minimis* adverse effects level) and will not be evaluated further. Site sediments that are significantly different from the reference sediments will be evaluated for biological effects as described below.

Biological Effects

Site stations that have significantly lower rates of survival or growth than reference stations will be evaluated for possible biological effects using numeric thresholds for each test and endpoint. Effects thresholds will be those developed in Washington Department of Ecology's (Ecology 2002) review of the toxicity testing information available for the two test species (ASTM 2000; USEPA 2000b). The thresholds developed by Ecology (2002) represent levels above which minor or potentially significant effects[27] are expected to occur. Each threshold level is based on either the absolute or relative difference in the observed response to site sediments in comparison with reference sediment (Table 6-4):

- Amphipod and midge percent mortality -
  - No effect where S-R (i.e., mortality in site sediments minus mortality in reference sediments) = 10%
  - Minor threshold where 10% < S-R = 25%
  - Significant threshold where S-R>25%.
- Amphipod growth
  - No effect where S/R (i.e., growth in the site sediment divided by that in the reference sediment) = 0.75
  - Minor effect where 0.6 = S/R < 0.75

[25] For example, the arcsine square root transformation will be used for data expressed as percentages.

[26] The alternative hypothesis in a one-tailed test will be that the response (i.e., survival or growth) in the site sediments is less than that in the reference sediment.

[27] Ecology (2002) uses regulatory nomenclature for Washington State in describing minor effects (SQS) and significant effects (CSL) thresholds.

  - Significant effect where S/R < 0.6.

- Midge growth
  - No effect S/R = 0.8
  - Minor effect where 0.7 = S/R < 0.8
  - Significant effect where S/R < 0.7.

Stations that exceed two minor effects thresholds or one significant effect threshold will be designated as stations of concern. These stations of concern will be the focus of further geo-spatial evaluation as described below.

Geo-Spatial Evaluation

Geo-spatial techniques (e.g., Goff 2003) will be used to identify areas of three or more adjacent stations where average sediment toxicity results exceed two minor or one significant effect threshold for biological effects. These areas will define the principal threat zone for sediment toxicity and will be the focus of sediment remediation strategies for the EE/CA.

Co-Occurrence of Chemicals of Concern

Multivariate statistical analysis will be undertaken to determine whether there is a relationship between observed levels of toxicity and concentrations of chemicals of concern for the site. Results of the multivariate analysis will be used in conjunction with the geo-spatial characterization described above for both bulk sediments and purged samples to qualitatively characterize the principal threat zone for sediment toxicity and determine whether remediation of any single substance or group of substances will effectively reduce sediment toxicity. Where sediment toxicity cannot be explained by the presence of chemicals of concern in sediments, sediment management strategies based on sediment toxicity rather than sediment chemistry will be explored.

6.2 PHYSICAL AND ENGINEERING CHARACTERISTICS

6.2.1 Rationale

A testing program will be performed to determine the sediment index properties and geotechnical engineering parameters within the preliminary RAA boundary. The physical characteristics of sediments are important in the evaluation of dredging and capping technologies, dredged material transport and disposal, dredged material behavior in a disposal site, potential short-term impacts at the dredge and disposal sites,

and capacity of existing sediments to provide foundation support for capping material. The justification for each test as it relates to the EE/CA is discussed in Section 5.5.

6.2.2 Sampling Strategy

Nineteen borings will be drilled to a depth of up to 15 feet below mudline (or refusal) to evaluate geotechnical properties and conditions within the preliminary RAA boundary. Most of these 19 borings are co-located with the borings for chemical analysis (described in Section 6.1.1). The borings will be distributed over the in-water site as follows (Figures 6-1 to 6-3):

- A line of four borings approximately 50 ft east the dock face, including one location between the Salt Dock and Dock 1, another location east of Dock 1, another location between Docks 1 and 2, and the fourth location east of Dock 2. (WB-26, WB-36, WB-41, WB-53)
- A cluster of three borings located upstream of Dock 1, with 1 boring located within 50 ft of the high water line and two others further offshore. (WB-23, WB-30, WB-32)
- A cluster of four borings positioned downstream of Dock 1, with 2 borings located within 50 ft of the high water line and two others 100 ft away. The borings will be placed in the vicinity of the former discharge pipe located downstream of Dock 1. (WB-8, WB-9, WB-11, WB-54)
- A cluster of four borings upstream and just downstream of Dock 2, with two borings located within 50 ft of the high water line and two others 100 ft further toward the channel. (WB-38, WB-39, WB-43, WB-44)
- A cluster of four borings located downstream of Dock 2, with two borings located within 75-100 ft of the high water line and two others 50 ft east and downstream of Dock 2. (WB-45, WB-47, WB-48, WB-50)

Borings will be positioned approximately 100-125 feet apart, except those located outside the dock face, which will be spaced at greater distances. Borings proposed for geotechnical and physical testing will be co-located with borings used to characterize sediment and water quality testing (i.e., CST, EET, DRET, SBLT, TCLP, ATT). More than one boring will be required at several of these locations for the collection of undisturbed samples and to provide enough sediment for all proposed tests.

A hollow-stem auger (or equivalent) advanced with a drill rig positioned on a barge will be used to complete the borings. Samples will be collected continuously at 2 foot intervals using a GUS or Osterberg Sampler and stainless steel Shelby tube. A large-volume split-spoon sampler may also be used for sampling (refer to FSP).

6.2.3 Analytical Strategy

The following tests will be performed on the 0- to 2-ft, 4- to 6-ft, and 8- to 10-ft samples[28] from borings within the preliminary RAA boundary.

- Grain size analysis by ASTM-D422 with hydrometer
- Atterberg limits by ASTM-D4318
- Specific gravity by ASTM-D854
- Moisture content/density by ASTM-D2216 / D2937
- Organic content by ASTM-D2974

Grain size and Atterberg limits will also be performed on selected samples collected within each boring. In addition, the following tests will be performed on selected relatively undisturbed samples from the borings.

- Consolidation by EM-1110-2-5027 Appendix D, modified for low loads
- UU triaxial shear stress by ASTM-D2850
- CU triaxial shear stress by ASTM-D4767

Selected sediment samples will be collected and analyzed for physical and geotechnical parameters listed in Table 6-5. The actual number of tests performed will be based on field observations.

6.3 DREDGED MATERIAL CHARACTERIZATION (WATER QUALITY)

6.3.1 Rationale

Representative large volume samples are required for evaluation of dredging and disposal design requirements (USACE/USEPA 1998).

Potential water quality impacts during dredging will be evaluated using the DRET, CST, EET, and SBLT data to assess disposal in a CDF. The assessment of offsite disposal in a Subtitle D landfill will be performed with landfill-specific acceptance criteria including hazardous waste determination, TCLP tests, and the DEQ ATT.

[28] The number of samples analyzed and selection of sample depths may change based on visual observations (e.g., grain size, color, debris, etc.) in each boring.

6.3.2 Sampling Strategy

A large-volume sample will be composited from several borings located between Dock 1 and mid-way between Docks 1 and 2 (WB-08, WB-09, WB-11, WB-54). This area is near the former outfall through which DDT manufacturing process residue was discharged during a portion of the first year of DDT production. This area has been shown to have the highest DDT concentrations in sediments within the preliminary RAA boundary. Figure 6-2 presents the proposed boring locations for the composite sample.

The compositing scheme for the large volume sample will consider the estimated volume of sediments containing the most elevated concentrations of DDTr from this area of the river. At a minimum, sediment will be collected from four locations to provide a sufficient amount of representative material for all tests.

6.3.3 Analytical Strategy

The following tests will be conducted on each composite sediment sample representative of the four areas described above.

- DRET (DiGiano et al., 1995)
- EET (USACE 2003)
- CST (USACE/USEPA 1998)
- SBLT (Myers et al. 1992)
- TCLP (EPA SW-846 Methods)
- DEQ ATT (OAR 340-109-0001)

A representative sample of the composite sediment used in the elutriate and SBLT testing will be analyzed for the following.

- Chlorinated pesticides by EPA Method SW846-8081A
- Semivolatile organics by EPA Method SW846-8270C
- Volatile organics by EPA Method SW846-8260B
- Metals by EPA Methods SW846-6020, -7471A
- Total organic carbon by EPA Method SW846-9060A (modified for sediments)

Baseline water testing and water samples generated from the elutriate and SBLT testing will also be analyzed for the following.

- Chlorinated pesticides by EPA Method SW846-8081A
- Semivolatile organics by EPA Method SW846-8270C
- Volatile organics by EPA Method SW846-8260B
- Metals by EPA Methods SW846-6020, -7471A
- Total organic carbon by EPA Method 415.1
- Total suspended solids by EPA Method 160.2

Table 6-5 presents the proposed sampling and testing for water quality samples.

6.4 DEBRIS SURVEY (DREDGING) AND DOCK ENCUMBRANCES

The nature and extent of debris within the project site RAA will need to be considered in development and evaluation of sediment capping and dredging technologies. Accordingly, a reconnaissance survey of the project area will be conducted to estimate the quantity and nature of surface debris. Additionally, boring logs will be reviewed to identify subsurface debris encountered during both historical and the proposed site investigations. This information will be compiled for consideration during the EE/CA and will also be useful for inclusion in the final design documents and remedial construction contract.

There are three large docks at the site, which have been out of service since 2001. The docks are primarily timber construction (but include four large concrete dolphins), supported by a dense network of timber, steel, and concrete pilings. Four stormwater outfall structures extend into the RAA boundary. The dock and outfall structures may impact the feasibility of sediment capping or dredging. The site characterization program will include a survey of these structures to verify their condition and catalogue the type and quantity of construction materials. It is anticipated that one or more of the docks may be removed as part of the removal action.

6.5 RECONTAMINATION SOURCE CHARACTERIZATION

Remedial measures for upland source control should be evaluated and considered effective before implementation of the RA for those COIs that could recontaminate sediments or drive the sediment RA. Upland source control work is underway and is being evaluated through an ongoing monitoring program. A groundwater monitoring program is an integral element of each of the upland remedial measures. Monitoring plans to establish source control effectiveness are provided in the IRM work plans for hexavalent chromium reduction (ERM 2005b) and in-situ persulfate oxidation (ERM 2005c). Additional monitoring could also be conducted within the in-water portion of the

site at a later date, if needed, after source control has been completed and upland groundwater monitoring shows a significant reduction in COIs. Groundwater monitoring offshore may include peepers, Trident and UltraSeep® technologies. These monitoring technologies were shown to be effective in the Portland Harbor RI groundwater monitoring study (Integral 2005c).

Stormwater monitoring may also be required prior to implementing the in-water remedy. A sampling and analysis strategy for groundwater and stormwater monitoring will be evaluated further in the EE/CA report.

Table 6-1. Proposed Subsurface Sampling and Chemical Testing in Support of EE/CA.

Station	Northing	Easting	Total Depth[1]	Sample Depths[1]	TOC	Total Chromium	Perchlorate	Chlorinated Pesticides	VOCs
WB-08			20	TBD	--	--	--	--	--
WB-09			20	TBD	--	--	--	--	--
WB-11			20	TBD	--	--	--	--	--
WB-23			10	TBD	--	--	--	--	--
WB-26			15	0-2, 4-6, 8-10	3	3	3	3	3
WB-27			15	2-4, 4-6, 8-10	3	3	3	3	3
WB-28			20	0-2, 4-6, 8-10	3	3	3	3	3
WB-29			15	2-4, 4-6, 8-10	3	3	3	3	3
WB-30			15	2-4, 4-6, 8-10	3	3	3	3	3
WB-31			20	2-4, 4-6, 8-10	3	3	3	3	3
WB-32			20	2-4, 4-6, 8-10	3	3	3	3	3
WB-33			10	2-4, 4-6, 8-10	3	3	3	3	3
WB-34			15	2-4, 4-6, 8-10	3	3	3	3	3
WB-35			<10	2-4, 4-6	2	2	2	2	2
WB-36			15	2-4, 4-6, 8-10	3	3	3	3	3
WB-37			<10	2-4, 4-6	2	--	--	2	2
WB-38			15	0-2, 4-6, 8-10	3	--	--	3	3
WB-39			15	0-2, 4-6, 8-10	3	--	--	3	3
WB-40			10	2-4, 4-6, 8-10	3	--	--	3	3
WB-41			10	2-4, 4-6, 8-10	3	--	--	3	3
WB-42			<10	2-4, 4-6	2	--	--	2	2
WB-43			15	0-2, 4-6, 8-10	3	--	--	3	3
WB-44			15	0-2, 4-6, 8-10	3	--	--	3	3
WB-45			<10	2-4, 4-6	2	--	--	2	2
WB-46			15	2-4, 4-6, 8-10	3	--	--	3	3
WB-47			15	2-4, 4-6, 8-10	3	--	--	3	3
WB-48			10	2-4, 4-6, 8-10	3	--	--	3	3
WB-49			15	2-4, 4-6, 8-10	3	--	--	3	3
WB-50			15	2-4, 4-6, 8-10	3	--	--	3	3
WB-51			10	2-4, 4-6, 8-10	3	--	--	3	3
WB-52			10	2-4, 4-6, 8-10	3	--	--	3	3
WB-53			10	TBD	--	--	--	--	--

Table 6-1. Proposed Subsurface Sampling and Chemical Testing in Support of EE/CA.

Station	Northing	Easting	Total Depth[1]	Sample Depths[1]	TOC	Total Chromium	Perchlorate	Chlorinated Pesticides	VOCs
WB-54			10	TBD	--			--	--
TOTAL					77*	32*	32*	77*	77*

Notes:
[1] Estimated in feet based on previous sampling in the area. Total depth and sample selection may change based on field observations.
* Does not include field and laboratory quality control sample analysis. Number of samples analyzed may change based on field observations.
TBD – To be determined in the field.

Table 6-2. Proposed Surface Sampling and Chemical Testing in Support of EE/CA

Station	Northing	Easting	Depth (ft)	Conventional Testing	Total Chromium	Chlorinated Pesticides	Perchlorate	Chloride	VOCs	Bioassays[1]
Upstream of Salt Dock										
WS-56			0-1	1	1	1	1	1		1
WS-57			0-1	1	1	1	1	1		1
WS-58			0-1	1	1	1	1	1		1
WS-59			0-1	1	1	1	1	1		1
WS-60			0-1	1	1	1	1	1		1
WS-61			0-1	1	1	1	1	1		1
Dock 1 to Salt Dock										
WS-23			0-1	1	1	1	1	1		1
WS-27			0-1	1	1	1	1	1		1
WS-29			0-1	1	1	1	1	1		1
WS-30			0-1	1	1	1	1	1		1
WS-31			0-1	1	1	1	1	1		1
WS-32			0-1	1	1	1	1	1		1
WS-33			0-1	1	1	1	1	1		1
WS-34			0-1	1	1	1	1	1		1
WS-35			0-1	1	1	1	1	1		
WS-36			0-1	1	1	1	1	1		
WS-55			0-1	1	1	1	1	1		
Offshore of Docks 1 and 2										
WS-37			0-1	1		1	1		1	

Table 6-2. Proposed Surface Sampling and Chemical Testing in Support of EE/CA

Station	Northing	Easting	Depth (ft)	Conventional Testing	Total Chromium	Chlorinated Pesticides	Perchlorate	Chloride	VOCs	Bioassays[1]
WS-40			0-1	1		1	1		1	
WS-41			0-1	1		1	1		1	
WS-42			0-1	1		1	1		1	
Downstream of Dock 2										
WS-45			0-1	1		1			1	
WS-46			0-1	1		1			1	
WS-47			0-1	1		1			1	
WS-48			0-1	1		1			1	
WS-49			0-1	1		1			1	
WS-50			0-1	1		1			1	
WS-51			0-1	1		1			1	
WS-52			0-1	1		1			1	
TOTAL				29*	17*	29*	21*	17*	12*	14*

* Does not include field and laboratory quality control sample analysis or reference sediments.
[1] Additional stations may be tested for bioassays pending the chemical results.

Table 6-3. Four Lines of Evidence for Judging Principal Threat to Sediments in the Vicinity of the Arkema Site.

1 Statistical Comparisons (*De Minimis* Threshold)	2 Individual Stations Exceed Biological Effects Thresholds	3 Geo Spatial Patterns	4 Chemicals of Interest
? Site vs. Reference	? 2 minor thresholds exceeded ? 1 significant threshold exceeded	? Solitary station ? Multiple stations	? Present ? Elevated ? Correlations with toxicity

Table 6-4. Biological Effects Thresholds for Interpetation of Sediment Toxicity Tests.

Hyalella azteca Mortality[1]	*Hyalella azteca* Growth[2]	*Chironomus tentans* Mortality[1]	*Chironomus tentans* Growth[2]
No effect S-R = 10%	No effect S/R = 0.75	No effect S-R = 10%	No effect S/R = 0.8
Minor effect threshold S-R >10% to = 25%	Minor effect threshold S/R < 0.75	Minor effect threshold S-R >10%	Minor effect threshold S/R < 0.8
Major effect threshold S-R > 25%	Major effect threshold S/R < 0.6	Major effect threshold S-R > 25%	Major effect threshold S/R < 0.7

[1] Expressed as the absolute difference of the result for the site sediment minus the result for the reference sediment (S-R).
[2] Expressed as the relative difference of the results for the site sediment divided by the result for the reference sediment (S/R).

Reference: Adapted from Ecology (2002).

Table 6-5, Proposed Borings for Engineering and Water Quality Evaluation.

Station	Northing	Easting	Depth	Index Parameters	Consolidation	Laboratory Shear Strength, Permeability	*In situ* Shear Strength	Elutriate Testing, SBLT	Column Settling Testing	TCLP, ATT
Offshore of Docks	**SAMPLE LOCATION AND NUMBER TO BE DETERMINED IN THE FIELD**									
WB-26										
WB-36										
WB-41										
WB-53										
Upstream of Dock 1	**SAMPLE LOCATION AND NUMBER TO BE DETERMINED IN THE FIELD**									
WB-23										
WB-30										
WB-32										
Downstream of Dock 1	**SAMPLE LOCATION AND NUMBER TO BE DETERMINED IN THE FIELD**									
WB-8								X	X	X
WB-9								X	X	X
WB-11								X	X	X
WB-54								X	X	X
Dock 2										

Table 6-5, Proposed Borings for Engineering and Water Quality Evaluation.

Station	Northing	Easting	Depth	Index Parameters	Consolidation	Laboratory Shear Strength, Permeability	*In situ* Shear Strength	Elutriate Testing, SBLT	Column Settling Testing	TCLP, ATT
WB-38										
WB-39										
WB-43										
WB-44										
Downstream of Dock 2	**SAMPLE LOCATION AND NUMBER TO BE DETERMINED IN THE FIELD**									
WB-45										
WB-47										
WB-48										
WB-50										

7.0 RA EVALUATION APPROACH

The primary goal of the NTCRA for the Arkema in-water site is to conduct an early RA of a principal threat area that reduces exposure of ecological and human receptors to sediment contamination, thereby reducing adverse effects on biological resources in the removal area. RAOs described in the AOC and presented in Section 5.1.1 were developed for the Arkema RA to meet this goal. The purpose of the EE/CA is to analyze the effectiveness, implementability, and cost of remedial alternatives that may satisfy these objectives (USEPA 1993a). Only the most qualified technologies that apply to the medium or source of contamination will be addressed in the EE/CA. A preliminary list of qualified technologies has been described in previous sections and includes:

- *In situ* capping
  - Isolation capping
  - Thin-layer enhancement capping
- Dredging and onsite disposal
  - Nearshore CDF (including in-water sheet pile wall)
- Dredging and offsite disposal
  - Subtitle C/D Landfill
  - Nearshore CDF
  - CAD
- Monitored natural recovery
- Treatment
- A combination of the above

Hydraulic containment may be required within the upland portions of the site to assure that source control measures are effectively reducing any principal threats and/or the potential for cap recontamination before implementation of the in-water RA. Construction of a sheet pile wall along the shoreline or in-water or other hydraulic or *in situ* source control measures may also be evaluated in the EE/CA.

The EE/CA will evaluate each one of these technologies (and possibly others) against three broad criteria: effectiveness, implementability, and cost. Subcriteria to be evaluated under each of these criteria are generally described in the EPA guidance document (USEPA 1993a) with specific screening criteria summarized below. Once the technologies have been evaluated relative to these criteria and subcriteria, a comparative analysis will

be conducted to evaluate and rate the relative performance of each alternative or technology. The result of this comparative analysis is a recommended removal action alterative for the site. A summary of the technologies to be considered in the EE/CA, along with key design considerations that will be evaluated as part of the screening process is described in the following sections.

7.1 CAPPING TECHNOLOGIES

Capping technologies involve the placement of a covering or cap over an *in situ* deposit of problem sediment. The cap may be constructed of clean sediments, sand, gravel, or may involve a more complex design with geotextiles, liners, carbon-activated material (amended cap), or other materials in multiple layers. Capping may be used to enhance natural recovery of the sediments or isolate the contaminated sediments. The screening criteria that will be used to evaluate the effectiveness, implementability, and cost of capping technologies for the RA may include the following.

Physical Isolation Component

- strength and compressibility of cap material and underlying problem sediments;
- depth of effective sediment mixing due to bioturbation and/or frequent sediment disturbance;

Stabilization/Erosion Protection Component (including Operation Conditions)

- stability of sediment slopes to be capped;
- impacts to water quality during cap placement;
- the presence of underwater debris;
- potential interference of the cap with navigation;
- the presence of piers, piles, stormwater pipes, and under-pier areas to be capped;
- periodic external loads on the cap, including seismic forces, erosion, propeller wash, and ice, as appropriate.

Chemical Isolation Component

- evaluation of partition coefficients of COIs;
- migration of dissolved contaminants by diffusion (movement across a concentration gradient) and advection (flow of groundwater or porewater);
- sorptive capacity of cap material; and

- hydraulic conductivity of cap materials, underlying problem sediment and clean sediment.

Analytical and numerical models are available to predict movement of contaminants into and through caps (USACE 1998, USEPA 1998). These models examine both the short-term transport of chemicals caused by consolidation, and the longer-term transport of chemicals caused by groundwater advection and diffusion processes. A form of this modeling may be conducted in preparation of the EE/CA.

Following this screening, a short list of capping technologies will be developed and will serve as the basis for developing RA alternatives.

7.2 DREDGING TECHNOLOGIES

Mechanical and hydraulic dredging technologies will be evaluated in portions of the RA where removal of contaminated sediment may be appropriate. The key design considerations that will be used to evaluate the effectiveness, implementability, and cost of dredging technologies for the RA include the following:

- resuspension of sediment and water quality impacts during dredging;
- dredging accuracy (vertical and horizontal);
- operating production rate;
- dredging depth;
- volume and characteristics of water generated from dredging operations;
- equipment availability;
- dredging support equipment requirements ;
- positioning control and ability to handle underwater obstructions, piers, riprap, and other debris; and
- site constraints, slopes, including water depths, underwater pilings (cut piles), and presence of piers;
- residual sediment management requirements; and
- dredge material transport options and disposal locations.

Following this screening, a short list of dredging technologies will be developed and will serve as the basis for developing RA alternatives.

7.3 DREDGED MATERIAL HANDLING TECHNOLOGIES

This section presents a summary of the technologies likely to be considered for the handling, treatment, and disposal of dredged sediment.

7.3.1 Dredged Material Transport Technologies

The EE/CA will discuss the various alternatives for dredged material handling and transport and their applicability to the RA. The first stage of the transport process is to move the dredged material to the disposal, staging, or rehandling site. Sediment may then be transported for dewatering, treatment (of sediment, water, or both), or disposal (USEPA 1994). Transport methods such as pipelines, barges, and transfer to truck and rail will be reviewed in the EE/CA. The key design considerations that will be used to evaluate the effectiveness, implementability, and cost of transport technologies for the RA may include the following:

- Dredging methods;
- Sediment physical properties that may affect sediment handling and pumping characteristics (specific gravity, gradation, water content, plasticity);
- Dredged material effluent water quality;
- Distance to disposal or temporary handling facilities;
- Physical constraints that may preclude transport by barge or pipelines;
- Location and availability of truck and train transloading facilities;
- Availability of upland area and resources for storage, handling, and processing of dredged material; and
- Availability of required equipment and contractor expertise.

7.3.2 Dredged Material Treatment Technologies

The treatment of contaminated sediment may involve a combination of processes including pre-treatment, operational treatment, effluent treatment, and residuals handling. Treatment technologies for sediment are generally classified as biological, chemical, extraction or washing, immobilization (solidification/stabilization), and thermal (destruction or desorption). In some cases, particle size separation is also considered a treatment technology. The key design considerations that will be used to evaluate the treatment technologies for the RA may include the following.

- Ability of treatment method to effectively destruct site chemicals of concern (or reduce volume of contaminated sediment);

- Ability of treatment method to accommodate the expected variation in chemical and physical properties of site sediments;
- Estimated quantity and characteristics of contaminated residuals generated from treatment process (solids, water, air emissions), and associated secondary treatment or disposal requirements;
- Demonstrated (full-scale) success of treatment method at similar sites (i.e., similar sediment chemicals, physical, and volume characteristics);
- Permitting requirements; and
- Treatment cost.

7.3.3 Dredged Material Disposal Options

The range of disposal options considered for the in-water RA may include upland disposal into an appropriate landfill, disposal in a nearshore CDF (constructed along the Willamette shoreline), and CAD. Each of these technologies will be evaluated for the RA and may include the following design considerations:

- requirement for dewatering or stabilization before disposal;
- hazardous waste characterization (TCLP, Oregon ATT);
- short-term releases (e.g., effluent, surface runoff)
- long-term releases (e.g., groundwater seepage, water column);
- availability; and
- permitting;

Following this screening, a short list of dredged material handling technologies will be developed to serve as the basis for developing RA alternatives.

7.4 MONITORED NATURAL RECOVERY

The following types of information and conditions will be required to support monitored natural recovery as an effective remedial technology for the site:

- Control of significant ongoing chemical sources;
- An understanding of the nature and extent of chemicals at the site;
- An understanding of natural processes affecting sediment and chemicals at the site (e.g., sedimentation and erosion processes);

- Evaluation of ongoing risks during the recovery period and exposure source control (period to be determined);
- Monitoring of natural processes, concentrations of chemicals in sediment, and toxicity to biota to determine whether recovery is occurring at the expected rate; and
- Predicting effects of natural processes in the future.

An important consideration in assessing whether monitored natural recovery is a viable alternative is to show that observed reductions in sediment and biological risks can reasonably be expected to continue into the future. Simple one-dimension models (e.g., SEDCAM) can be useful tools for predicting these conditions in the future and may be included in evaluating this technology in development of RA alternatives. A form of this modeling may be conducted in preparation of the EE/CA for the site.

8.0 PROJECT SCHEDULE

A schedule for the RA project is outlined in the AOC Appendix B (Statement of Work) and includes the following:

Schedule of Project Deliverables (from AOC Statement of Work)		
Engineering Evaluation/Cost Analysis (EE/CA) Work Plan	Draft EE/CA Work Plan	Within 90 days after effective date of AOC.
	Final EE/CA Work Plan	Within 30 days after receipt of EPA comments on draft.
Upland Source Control	Upland Source Control Evaluation Report	Evaluation of upland source control will be completed in accordance with the schedule in the final EE/CA work plan.
Removal Action Area Characterization Report	Draft Removal Action Area Characterization Reports	Within 150 days after EPA approval of the EE/CA Work Plan unless otherwise approved in the schedule in the Final EE/CA Work Plan if adequate justification is given and is approved by EPA.
	Final Removal Action Area Characterization Report	Within 30 days after receipt of EPA comments on draft Report.

Schedule of Project Deliverables (from AOC Statement of Work)		
Engineering Evaluation/Cost Analysis (EE/CA) Report	Technical Briefing on Proposed Remedial Alternatives	Within 30 days after approval of the Final Removal Action Area Characterization Report by EPA.
	First Draft EE/CA	Within 90 days of the Technical Briefing on Proposed Removal Alternatives.
	Second Draft (Public Review) EE/CA	Within 60 days after receipt of EPA comments on first draft EE/CA.
	Final EE/CA	Within 60 days after receipt of EPA comments on second draft EE/CA.
Biological Assessment and 404 Memorandum	Draft Biological Assessment and Draft Clean Water Act Section 404 Memorandum	Submitted with draft EE/CA
	Revised Biological Assessment and Revised Clean Water Act Section 404 Memorandum	Submitted with revised draft EE/CA, within 60 days after receipt of EPA comments on first draft EE/CA.
	Draft Final BA	If the ESA agencies determine that additional design information is necessary for a final BA, then a draft final BA shall be due as determined by the ESA agencies.

Schedule of Project Deliverables (from AOC Statement of Work)		
Project Design Documents	Conceptual (30 percent) Design	Within 90 days of EPA signature of the Action Memorandum.
	Prefinal (90 percent) Design	Within 90 days after receipt of EPA comments on conceptual design.
	Final (100 percent) Design	Within 60 days after receipt of EPA comments on prefinal design. The above deadlines may be modified in accordance with the schedule in the EE/CA final report if adequate justification is given and is approved by EPA.
Removal Action Work Plan	Draft Removal Action Work Plan	Within 60 days after EPA approval of the Contractor or in accordance with the schedule in the 100% design deliverable, if changes are justified in the document and approved by EPA.
	Final Removal Action Work Plan	Within 30 days after receipt of EPA comments on draft Removal Action Work Plan.
Implementation of Removal Action	Notification of Removal Action Start	Provide notification to EPA 30 days prior to initiation of Removal Action fieldwork to allow EPA to coordinate field oversight activities.
	Removal Action Start	30 days after Notification Removal Action

Schedule of Project Deliverables (from AOC Statement of Work)		
Removal Action Completion Report	Draft Removal Action Completion Report	Within 60 days after completion of Removal Action (construction phase).
	Final Removal Action Completion Report	Within 30 days after receipt of EPA comments on Draft Removal Action Completion Report.
Long-Term Monitoring and Reporting Plan	Draft Long-Term Monitoring and Reporting Plan	Within 60 days after EPA approval of the Final Design.
	Final Long-Term Monitoring and Reporting Plan	Within 60 days after completion of the removal action and receipt of EPA comments.
	Monitoring Data Reports	Schedule to be proposed by Respondent in the Long-Term Monitoring and Reporting Plan.

The project coordinators (for both Arkema and EPA) will be responsible for overseeing implementation of the AOC and meeting the schedule for project deliverables. As previously stated, Arkema and EPA entered into an AOC on June 27, 2005, which represents the first major milestone for the project. Once the AOC was signed, a review of existing studies was initiated by Arkema and its consultant to identify data gaps. This information shaped the development of the investigation program and the development of this draft EE/CA Work Plan.

As specified in the AOC, the draft EE/CA Work Plan will be submitted to EPA and stakeholders for review and comment. Agency approval of the final EE/CA Work Plan represents the second major milestone for the project.

The EE/CA report will be produced following completion of the site characterization study and the Removal Action Area Characterization Report (third major milestone). The final EE/CA represents the fourth major milestone in the project. The final EE/CA is tentatively scheduled for completion in June 2007. The final Biological Assessment (BA) and 404 Memorandum are scheduled for completion in October 2007, which represents the fifth major milestone. The sixth major project milestone is EPA issuance of the Action

Memorandum estimated for completion in December 2007. The timing of these major milestones is shown graphically in Figure 8-1. Note that to produce this schedule, assumptions were made about the period of time required for EPA review of Arkema documents and for coordination of in-water work with the fish window. These review periods and fish window requirements are not defined in the AOC.

Appropriate upland source control should be completed soon after the final EE/CA, which represents another major milestone in the project. A condition of the statement of work (SOW) to the AOC requires Arkema to continue to work under DEQ supervision on upland source control actions. The SOW states that the goal is for significant upland sources to be controlled to the greatest extent practicable before or during RA implementation such that significant post RA recontamination is not predicted.

The EE/CA Report, which is tentatively scheduled for completion in the summer of 2007, will include the critical environmental evaluation (including evaluation of cleanup levels) for project decision-making and selection of a preferred cleanup action for the RAA. Actual implementation of the removal action is tentatively scheduled for early summer of 2009.

Arkema's upland source control activities are targeted for substantial completion by October 2007. The majority of the work anticipated under the groundwater and soil IRMs will be complete or nearly complete by that date. The goal of the ongoing upland in-situ groundwater source control IRMs for chromium reduction and chlorobenzene oxidation is to achieve the appropriate chronic water quality criteria in monitoring wells adjacent to the riverbank. If the IRMs have not fully achieved the goal but are showing a continuing trend towards achieving upland source control, additional work may be scheduled in late 2007 to complete source control such that recontamination of a sediment remedy is not anticipated. The evaluation of upland source control activities is an ongoing process that will extend through the fall of 2007.

The SOW also states that as a result of the upland source control evaluation, should it be determined that sources are not being controlled sufficiently to achieve the RAOs, EPA may require Arkema to conduct an evaluation of hydraulic control measures in the EE/CA, such that the removal action may occur without the expectation of recontamination.

If it is determined that upland source control efforts are not on track to prevent unacceptable recontamination of sediment, the time period for implementation of hydraulic containment measures is during 2008.

It is important to note that some constituents on the Arkema site, such as chloride, are highly soluble and will pass through sediments. Upland sources of chloride, salt and brine, were removed from the plant site shortly after plant shutdown in 2001. Monitoring

of chloride concentrations in plant groundwater since plant shutdown has shown a continuing decrease in chloride concentrations. Arkema is not anticipating upland source control for chloride and proposes to continue to monitor the decrease of concentrations. Perchlorate is also not anticipated to adsorb onto sediments and should not directly impact the timing of the in-water remedy. Arkema is continuing to assess the treatability of perchlorate in upland groundwater.

Other major milestones on the project include the completion of project design documents, implementation of the Removal Action, and the Removal Action Completion Report. An estimate of completion for these major project milestones will be provided in the final EE/CA

9.0 PROJECT TEAM AND RESPONSIBILITIES

Figure 9-1 shows the team and organization for the Removal Action; the roles of the team members are discussed below.

Arkema Inc. The project coordinators (for both Arkema and EPA) will be responsible for overseeing implementation of the AOC, including the development of the EE/CA. **Larry Patterson, P.E.**, is the designated Arkema project manager and will coordinate all activities with the EPA and DEQ project coordinators. Mr. Patterson will be responsible for contracting with and directly supervising the environmental consultant(s) that will conduct the field, lab, analysis, and reporting tasks for the EE/CA. He will direct the consultant on a day-to-day basis and provide primary review of all reports and other work products. Mr. Patterson will also coordinate with EPA regarding the AOC for the Removal Action of the site.

Integral Consulting Inc. Integral was selected by Arkema to conduct the EE/CA for the Portland Harbor site and is responsible for writing work, implementing the field program, including field sampling, and laboratory analysis, data analysis, and reporting. **David Livermore**, a Registered Geologist in Oregon, is the Integral project manager and will serve as the point of contact for Arkema. He will be responsible for implementing and executing the technical, QA, and administrative aspects of the EE/CA, including the overall management of the project team. Mr. Livermore will be responsible for the quality and timeliness of Integral documents. Mr. Livermore will be assisted by **Mark Herrenkohl**, the EE/CA Task Manager. Mr. Herrenkohl is accountable for ensuring that the EE/CA is conducted in accordance with applicable plans and guidelines, including the Work Plan, SAP, QAPP, and HASP. He will communicate all technical, QA, and administrative matters to the Integral and Arkema project managers. He will ensure that any deviations from the approved work plans are documented, communicated to Arkema, and approved before implementation.

The project engineer, **Reid Carscadden, P.E**., will assist the project and task managers with the EE/CA activities of the project, including an evaluation of remediation alternatives for the site.

Les Williams, Ph.D. will lead the ecological and human health risk screening for the Arkema site.

The overall management of the project-specific QA activities is the responsibility of the QA manager, **Laura Jones**. Ms. Jones is responsible for implementation of site-specific QA activities, including field and laboratory quality control. In addition, the QA manager

will coordinate with the Integral project and task managers and other project staff, as applicable, during the reduction, review and reporting of analytical data.

The Integral Health and Safety Manager, **Eron Dodak**, is responsible for the implementation of the site-specific HASP. Mr. Dodak, who will also be the field operations manager, will advise the project staff on health and safety issues, conduct health and safety training sessions, and monitor the effectiveness of the health and safety program conducted in the field.

The field operations manager, Mr. Dodak, will be responsible for managing and supervising the field investigation program and providing consultation and decision-making on day-to-day issues relating to the sampling activities. The field manager will monitor the sampling to ensure that operations are consistent with plans and procedures and that the data acquired meet the analytical and data quality needs. When necessary, the field manager will document any deviations from the plans and procedures for approval. The field operations manager will be assisted in the field by other technical personnel to be determined.

The services of several subcontractors (e.g., drilling contractor, land surveyors, laboratory services) will be necessary for the performance of the field investigation and implementation of project objectives. The EE/CA task manager, with assistance from the field manager, as necessary and appropriate, will be the primary liaison between Integral, the Arkema Project Manager, and each of the subcontractors. Subcontractors are responsible for performing work according to the requirements in this work plan.

Columbia Analytical Services, Inc. (CAS) of Kelso, Washington, will perform the chemical and physical analyses of water, soil, and sediment samples collected for this project. Northwest Aquatics Services, Inc. (NAS) of Newport, Oregon, will analyze the bioassay samples. The drilling and surveying contractors have not yet been determined. The project manager for each subcontractor will be responsible for coordination with Integral, FSP/QAPP implementation, and analytical data quality.

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